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Great Britain —  
MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE  
GEOLOGY OF LONDON  
AND OF  
PART OF THE THAMES VALLEY.

(EXPLANATION OF SHEETS 1, 2, AND 7.)

BY  
*William*  
W. WHITAKER, B.A., F.R.S.,  
F.G.S., Assoc. Inst. C.E.

VOL. I. DESCRIPTIVE GEOLOGY.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.



LONDON:  
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.  
BY EYRE AND SPOTTISWOODE,  
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1889.

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Sci 2490.75.20

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(2 vol)

## P R E F A C E.

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IN the year 1872 an account of "The Geology of the London Basin," Part I., was published as Vol. IV. of the Memoirs of the Geological Survey of Great Britain. This volume, written mainly by Mr. Whitaker, with contributions from Mr. Bristow, Mr. Hughes, and others, was intended to supersede, wholly or in part, three of the Sheet Memoirs, viz., those of Sheets 7, 12, and 13, and to form a convenient compendium of the geology of the London Basin. It was meant to be followed by a second part, which was to include a detailed account of the superficial formations of the district. In the progress of the Survey, however, it has been found desirable to modify this plan of publication. The projected second part has not been published, and the Memoir as it stood in Vol. IV. will not be reprinted. The present work, though not strictly a new edition of that Memoir, will practically take its place, while other Sheet Memoirs will supply the information for the areas not here included. The volume describes the geology of London and its surrounding districts, including not only the Mesozoic and Tertiary formations, but also the Superficial deposits. The Sheets of the Geological Survey Map which it describes are thus Sheets 1, 2, and 7, with some marginal parts of 6 and 8. It consequently covers a small portion of country not embraced in "The Geology of the London Basin" and omits the outlying areas which were there described. Making London its centre, it takes in the easily accessible districts around, along the valley of the Thames, and will thus, it is hoped, be found to furnish in a convenient form the information which those interested in the geology of London and its neighbourhood may wish to obtain.

In the preparation of the present Memoir free use has, of course, been made of material published in former Memoirs, which have been advisedly allowed to go out of print. Thus the account of the Cretaceous and of the Eocene strata to the west of London is taken (with large additions and some corrections) from the Memoir on Sheet 7 and from the "Geology of the London Basin." But a great portion of the following pages appears for the first time.

Among the more important matters now for the most part first published is the detailed account of the superficial deposits of the London district, which may be regarded as practically filling the place originally intended to be occupied by the second part of "The Geology of the London Basin." The Appendices of Borings and of Sections seen in London foundations, as well as the

descriptions of the ancient rocks revealed by deep borings below the Secondary formations of London are new. Many and extensive additions have likewise been made to those portions which have already appeared in former Memoirs. In particular, the Appendix of Well-sections has been greatly augmented, and as it now appears can hardly fail to be still more useful than heretofore in questions of water-supply and drainage, wherein the practical value of such details is now everywhere recognized.

To Mr. Whitaker belongs the merit of arranging the whole material and of writing by much the larger part of this Memoir. His name has been so long and honourably associated with the geology of London, and he has been so widely recognized as a careful and accurate geologist, that I feel confident this new work will be accepted as an important contribution to the geology of the Cretaceous, Tertiary, and Pleistocene formations of the south-east of England. Mr. Jukes-Browne has supplied some of the descriptions of the Cretaceous beds, for the most part from his own re-survey of the ground.

The work of other observers outside of the Geological Survey, whether in the form of published papers or of private information, has been freely used and fully acknowledged in the text and in the Appendices. It is only by the co-operation of many independent workers that the details of the numerous fresh sections that are continually being opened can be secured and recorded before they are destroyed or concealed. Such co-operation is rendered much more effective by the various Field-clubs and Societies now established round London, and it is hoped that henceforth no section of importance will be laid open and covered up again without being carefully noted by local observers. The Geological Survey will thankfully receive any such notes which these observers may be willing to communicate, with a view to incorporation in any subsequent edition of this work.

A summary of the literature of the several sub-divisions of the volume has been given. Among the authors cited no name occurs more frequently than that of Professor Prestwich. It would be impossible to publish another contribution to the geology of London and the south-east of England without an acknowledgment of the deepest obligation to his prolonged researches and of the warmest admiration for the breadth, accuracy, and insight which have marked his contributions to geological literature.

ARCH. GEIKIE.

*Geological Survey Office,  
28, Jermyn Street, London,  
16th February 1889.*

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Chaps. 4-6 are almost wholly by MR. JUKES-BROWNE.



# THE GEOLOGY OF LONDON, ETC.

## CHAPTER I. INTRODUCTION.

### AREA.

The district described in this Memoir is about 1,860 square miles in extent, and is represented on Sheets 1, 2 and 7 of the Geological Survey Map, with a small piece of the north-western corner of Sheet 6 (up to the escarpment of the Tertiary beds, by Addington, Farnborough, and the Valley of the Cray), and with a larger piece in the north-eastern quarter of Sheet 8 (up to the same escarpment westward from the Valley of the Mole, by the succession of villages to Croydon). The extreme southern end of Middlesex, which just reaches into this Map, is also included.

This tract includes the whole of the County of MIDDLESEX, and parts of all the adjoining counties, as follows, taking first those north of the Thames, and then those on the south, from west to east :—

County.	Towns, etc.
<i>Oxfordshire.</i> Extreme eastern end.	—
<i>Buckinghamshire.</i> Southern part.	Amersham, Beaconsfield, Chesham, Colnbrook, Great Marlow, High Wycombe, Prince's Risborough, Wendover.
<i>Hertfordshire.</i> Southern end.	Barnet, Berkhamstead, Hoddesdon, Rickmansworth, St. Albans, Watford.
<i>Essex.</i> Southern part.	Barking, Billericay, Brentwood, Burnham, Chelmsford, Chipping Ongar, Epping, Ingatestone, Maldon, Rayleigh, Rochford, Romford, Southend, Stratford etc., Waltham Abbey.
<i>Berkshire.</i> Northern part of eastern end.	Maldenhead, Windsor.
<i> Surrey.</i> Northern end.	Croydon, Epsom, Kingston, Richmond, and southern London.
<i>Kent.</i> Northern border of western half.	Bromley, Dartford, Gravesend, Greenwich, Woolwich.



## RIVERS.

*The Thames.*

Our chief river has its origin in many streams, which rise far beyond our present bounds, and in beds much lower than any that crop out in our district. It cuts through the great Chalk escarpment near Wallingford, and thence, flowing in a general easterly course, runs through the southern part of our district from west to east, entering at Shiplake and then flowing irregularly over the Chalk to between Maidenhead and Windsor, where it enters the Tertiary tract, in which it continues its course to below London, except for crossing the inlier of Chalk at Windsor. It seems just to touch Chalk again at Woolwich, returns to that formation at Erith, and keeps to it to a few miles below Gravesend, where it finally enters the trough of the Tertiary beds.

"The ordinary rise of the tide is, at the Nore 14 feet, and at London Bridge about 17 feet: its influence is now felt as far as Teddington, where the low-water level is 16 feet 9 inches above that of London Bridge, and the high-water level 1 foot 6 inches above ordinary high-water mark at that spot; the distance being 19 miles, and the fall of the bed of the river about 12 inches per mile. The influence of the tide extends therefore about 60 miles, the first portion of which, from the Nore to London Bridge, a distance of about 40 miles, is traversed by the tidal wave in two hours, and the remaining 20 miles in the same time. The Thames receives the drainage of more than one-seventh part of England."\*

With the exception of some streams in the north-eastern part of our district (see p. 5), the Thames receives all the drainage, and when England extended further eastward the exceptional Essex streams were probably tributaries. The inflowing of the various tributary streams has been quaintly put by SPENSER in the following words:—

"The noble Thames, with all his goodly traine,  
But before him there went, as best became,  
His auncient parents, namely th' auncient Thame;  
But much more aged was his wife than he,  
The Ouze, whom men doe Isis rightly name;  
\* \* \*

And round about him many a pretty Page  
Attended duely, ready to obay;  
All little Rivers which owe vassallage  
To him, as to their Lord, and tribute pay:  
The chaulky Kenet; and the Thetis gray  
The morish Cole; and the soft-sliding Breane;  
The wanton Lee, that oft doth loose his way;  
And the still Darent, in whose waters cleane  
Ten thousand fishes play and decke his pleasant streame.  
\* \* \*

And Mole, that like a nousling mole doth make  
His way still under ground till Thames he overtake."†

\* H. ROBINSON, "On the past and present Condition of the River Thames," *Proc. Inst. Civ. Eng.* vol. xv. p. 196.

† "Faerie Queene," book 4, canto 11, verses 24, 29, 32.



5. The *Yedding Brook*, the result of the drainage of the London Clay tract between Uxbridge and Harrow, flows into the *Thames* at Isleworth.

6. The *Brent*, formed from the drainage of the same formation between Harrow, Barnet, and Hampstead, and the springs on the north-western side of the outlier of Bagshot Sand at the last place, pays its tribute at Brentford, after a course of 10 miles.

The short streams that once flowed from the Bagshot Sand and the London Clay of Hampstead and Highgate have been suppressed, in the process of metropolitan extension.

7. The *Lea* enters the district at Hoddesdon, flows southward, and joins the *Thames* at Blackwall, being tidal up to Lea Bridge.

Various small Tertiary brooks add their little to the *Lea*, on its western side, such as that from the Northaw inliers etc. which joins near Enfield Wash, *Salmon's Brook*, from the Drift and the London Clay westward of Enfield, and *Pymme's Brook*, from the same formations eastward of Barnet, which join near Edmonton.

On the east the *Lea* receives, near Waltham Abbey, *Cobbins Brook*, from the clay-country north of Epping, and the streamlet from High Beech, which joins below Chingford, besides other tiny runlets of clay-drainage.

8. The *Roding* is a Tertiary stream, rising west of Dunmow (beyond the district, in Sheet 47) and flowing into the *Thames* marshes at Barking.

9. The *Bourne*, which is chiefly the drainage of a clay-tract, flows from north of Havering southward to Dagenham.

10. The *Ingrebourne*, of like character, starts from north of Southweald, flows southward and joins the *Thames* at Dagenham.

11. The *Mar Dyke*, formed by the various water-channels from the London Clay etc. from Great Warley to Langdon (or Laindon) Hill, which come together at Bulphan. The resultant stream flows southward for a short way, and then south-westward to the *Thames* at Purfleet.

This stream therefore forms an exception to the general rule that a tributary joins a main stream in a direction tending to that of the flow of the main stream.

Below this the *Thames* receives hardly anything on its left side, the little stream at Stifford being the only noticeable flow: in fact the river here comes close to the boundary of its present watershed.

#### *Streams flowing into the Thames from the South.*

12. The *Loddon* just enters the district, on the west, joining the *Thames* at Wargave, and draining the Tertiary tract between Ruscomb and Binfield.

From Maidenhead south-eastward, to beyond our district, the *Thames* receives only very short streams on its right side, with which side we are not here concerned (passing the *Wey*) until reaching the next river.

13. The *Mole*, which is the border of the district now to be described, from where it enters the Tertiary beds on the south, at Leatherhead, to its junction with the Thames at East Molesey.

14. The *Hog's Mill Brook* rises at or near the junction of the Tertiary beds with the Chalk, at Ewell and Epsom, flows across and receives some of the drainage of the London Clay district, and joins the *Thames* at Kingston.

15. The small stream (the *Beverley*?) that rises in the Tertiary beds near Cheam flows over the London Clay to the north and receives the surface-drainage and the gravel-springs of the eastern side of Richmond Park and the western side of Wimbledon Common and of Putney Heath, joins the *Thames* at Putney.

16. The *Wandle* rises from the Chalk and Tertiary beds at Croydon: flows westward along the line of strike of the latter to Carshalton; and then northwards, to the *Thames* at Wandsworth.

17. The *Ravensbourne* rises in the Tertiary valley at Hayes and thence flows northward to the *Thames* at Deptford, receiving other drainage from the Tertiary district by the way.

18. The *Darent* enters the district on the south only about four miles from its junction with the Thames, north of Dartford, receiving on its way the tributary *Cray*, which rises in the top part of the Chalk at Orpington, flows northward along the escarpment of the Tertiary beds, then through them to Crayford, and thence north-eastward, through a gravel-covered Chalk flat, until it joins the *Darent* north of Dartford, its course being 9 miles long.

Below the Darent the Thames is joined, on its right side, by only very short streams, which for the most part merely wander through the bordering marsh.

#### *Streams not joining the Thames.*

The estuary of the *Medway* forms the extreme south-eastern border of the district for a few miles, and receives the drainage of the small Tertiary tract southward and eastward of High Halstow.

The *Crouch* has its origin in various streams that rise from the Drift and the Tertiary beds between Langdon Hill and Billericay, and flows eastward to the sea north of Foulness Island. It receives small tributaries, the drainage of the tract of London Clay, and soon becomes tidal, receiving in its estuary, above Foulness Island and not far above its entrance into the sea, the *Roach*, which is the product of the drainage of the Tertiary tract eastward of Hadleigh, Rayleigh, and Hockley, the various carriers of which unite into a tidal stream near Roohford, that flows east-north-eastward; but also communicates with the sea southward, by a set of creeks which cut off Foulness and other islands.

The *Blackwater* enters the extreme north-eastern corner of our district and soon becomes tidal. Just above Maldon it receives the *Chelmer*, which flows eastward from Chelmsford, and is the resultant of the drainage of a large tract of Drift and of

Tertiary beds on all sides of that town, but in great part north of our boundary. The chief tributaries are the *Wid*, from near Brentwood and Billericay, and the *Cann* and the *Ter*, on the north. From Maldon the tidal stream flows eastward to the sea (the estuary being for the most part fairly broad), and receives some small short streams on either side.

### GEOLOGICAL FORMATIONS.

The following table shows, on the right hand, the geological divisions that are coloured, or otherwise marked, on the maps of the district, whilst the other columns give their classification:—

	Recent Deposits -	{ Shells and Shingle, shown only by engraved words or dotting. Alluvium.
	River Drift -	{ Brickearth or Loam. Gravel and Sand.
Post Pliocene	High Level Drift, or deposits, of doubtful age.	{ Brickearth Clay-with-flints } of the Chalk-tract. Plateau Gravel.
	Glacial Drift -	{ Boulder Clay. Brickearth or Loam. Gravel and Sand.
Doubtful age	- - -	- Pebbly Gravel.
	Bagshot Beds -	{ Pebble Beds. Sand.
Eocene	-	London Clay.
	Lower London Tertiaries	{ Blackheath (or Oldhaven) Beds. Woolwich and Reading Beds. Thanet Sand.
	Chalk - -	{ Upper Chalk. Middle Chalk.
Cretaceous	-	{ Lower Chalk with its bottom-part Chalk Marl separate.
	Upper Greensand	{ Sand. Stone. Gault.

It should be noted that the divisions of the Chalk are not yet engraved on Sheet 7.

Besides the above, however, other formations that do not crop out in the district, and which indeed, with one exception, are not to be seen at the surface for some distance from it, have been proved, by deep borings for water, to occur underground. These are as follows:—

Cretaceous?	-	? Lower Greensand, very little.
Jurassic	-	- Great Oolite Limestone (3 places).
Trias?	-	- Red and grey Sandstone and Marl (4 places).
Devonian	-	- Purple shales (2 places).

Just beyond the district two other formations have been proved underground in like manner, the Oxford Clay (Jurassic), on the south-east, and Wenlock Shale (Silurian), on the north. It is likely, therefore, that further borings may result in proving the existence of other formations next beneath the Cretaceous deposits.

In looking through the list of deposits that occur at the surface, it will be seen that between the Pebbly Gravel and the Bagshot

Pebble-beds is a great gap, partly caused by the absence of the higher parts of the Bagshot Series from our district, though these come on near by to the south-west; but still more owing to the absence over the whole of the large tract of the London Basin, of those thick masses of Fluvio-marine formations that occur in so large a part of the Hampshire Basin, in which tract, on the other hand, there is no trace of the still newer, but much thinner, sheets of the Craggs, which are the chief feature of the north-eastern part of the London Basin. Regularity is the rule up to the Bagshot Beds; but after these irregularity, the various Drift gravels, etc., resting irregularly on the older beds.

The formations will be described in their natural order, that is, upwards from the oldest (those found only underground being first treated collectively); but it may be as well now to notice in a few words the area taken up by each.

The *Gault*, our lowest outcropping formation, takes up an area of more than 6 square miles, in the north-western corner of the district.

The *Upper Greensand* borders this, with an area of about 4 square miles.

The *Chalk* has a very broad outcrop, the narrowest part, at the north-western part of the district, being 11 miles broad, from near Prince's Risborough to the spur of the Tertiary beds westward of Beaconsfield. This northern outcrop however is much masked by masses of superficial deposits, together with Tertiary outliers, so that the Chalk is mostly hidden over the higher grounds.

Of the 4 divisions that have been mapped the *Chalk Marl* and the rest of the *Lower Chalk* come to the surface only along the lower part of the great escarpment, on the north-west; the *Middle Chalk* extends from the higher part of that escarpment southwards for some way along the valleys; whilst the *Upper Chalk* occurs over the higher grounds between the valleys and in the lower southern parts of the valleys themselves: this division therefore takes up a far greater area than all the others together, disregarding the tracts of Drift and surface-deposits.

On the south-east we are concerned only with a small part of the outcrop, bordering the Thames, and all of Upper Chalk.

The *Lower London Tertiaries* everywhere separate the Chalk from the London Clay, mostly with a narrow outcrop, though sometimes, on the south-east, with a broad one. All the three divisions however are present together only locally, and the middle division alone is persistent throughout. Outliers occur in great number, scattered far and wide over the Chalk-tracts. The *Thanet Sand* borders the Chalk-tract with a very narrow outcrop in Surrey, widening slightly in the neighbouring county of Kent, and coming up again over a length of about 8 miles in the southernmost part of Essex. The *Woolwich and Reading Beds* follow the course of the Thanet Sand, on the south, with an outcrop often equally narrow. On the north of the Basin however this division rests at once on the Chalk,

forming a very winding and mostly narrow band, from the south-western corner of the district north-eastward to Hatfield Park. The *Blackheath (or Oldhaven) Beds* occur only eastward of a line from Croydon to Greenwich, between which however and a nearly parallel line down the left side of the valley of the Cray, from Farnborough to Erith, they form the greater part of the surface. In Essex they crop out only for about  $3\frac{1}{2}$  miles, from Orsett eastward.

The *London Clay*. Were it not for the valley-bottoms, with their sheets of gravel and brickearth and the marshes bordering their streams, this formation would stretch across the district, from north to south and from east to west, in a continuous spread, within the area defined by the outcrop of the underlying beds. Outliers too are not uncommon, though less so than is the case with the Lower London Tertiaries. In the north-eastern part of our district the London Clay is much covered by Glacial Drift.

The *Bagshot Beds* occur only in detached masses, on high ground, the main mass of the Series coming on just southward of the western end of the district, and the lower division only is represented.

The *Pebbly Gravel* forms cappings to some of the higher ground of the Tertiary beds, and occurs also on a few of the outliers.

The *Glacial Drift* has not yet been found south of the Thames, and the gravel classed therewith in the western part of our district is so classed with some doubt. As a rule the *Gravel and Sand* here occurs on parts of the higher grounds, though often reaching down to the bottom of the valley of the Colne, in Hertfordshire, and to those of the Chelmer and of the Roding, in Essex. The *Boulder Clay* is chiefly confined to the north-eastern tract, where it is mostly on high ground, either as part of a large sheet, or as detached masses, sometimes of good size. Northward and north-westward of London there are only isolated patches. For the most part this clay rests on the London Clay, in the absence of the gravelly beds that sometimes separate the two clays.

The *Plateau Gravel* includes deposits of small area and of doubtful age, on fairly high ground, in the Tertiary tract, and which, in some cases (in Essex), rest on Boulder Clay.

The *Clay-with-flints*, and the associated *Brickearth*, which irregularly cover the higher grounds of the Chalk, to a large extent, in the north-western part of the district, are also of doubtful age.

The *River Drift*, consisting mostly of *Gravel*, but partly of *Brickearth*, occurs chiefly along the valley of the Thames, in part as a low flat tract bordering the river (as is mostly the case above London), and in part as a set of terraces rising fairly above the river and in many cases at considerable heights above it, on the flanks of the valley. In the latter position the gravel often occurs as detached masses, the relics of former continuous sheets.

Of the other valleys, that of the Lea alone contains any large amount of gravel.

The *Alluvium* or marsh-land occurs along either side of the Thames below London; whilst above there is singularly little. Along the other rivers there are also strips of marsh, mostly narrow, but broader along the Lea, the lower part of the Colne, and the tidal ends of the Crouch and of the Blackwater.

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It may be well to notice the underground course of such of these formations as are below the London Clay.

The *Gault* can be practically taken as continuous underground, from its northern to its southern outcrop, wide apart as they are; for every boring that has been carried far enough has met with this clay, and has proved it to be of good thickness.

The *Upper Greensand* thins out eastward, beyond our district, both on the north and on the south, and, though it is present in all our deep borings (except that at Bushey, north-west of London), it is absent in those at and near Chatham, near our southern border.

The *Chalk* is perfectly continuous, all the divisions being present, as far as we know, but perhaps not the highest beds of the Upper Chalk.

Whilst the *Lower London Tertiaries* as a group are continuous underground, yet the three divisions are not so, as our well-sections show. The *Thanet Sand* thins out westward, and for the most part northward also. The middle division alone, the *Reading Beds*, always occurs, being pierced in all the many wells carried through Eocene beds to the Chalk. The *Blackheath Beds* seem to thin out both northward and westward, within a few miles of their outcrop, their only distant occurrence underground yet recorded being near Southend.

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The plan followed in this Memoir is first to notice the general nature of each of the various formations; then to describe in detail its range, lithological character, and sections, working from west to east (that being the direction in which the Geological Survey went on); the southern tracts being generally taken before the northern, and in each a topographical arrangement being adopted, subject to which the Main Mass is first treated of, and then the Outliers.

Any section that shows more than one formation will be described at length in one place, as it would clearly be awkward to give part at one place and the rest at another.

The disturbances which the beds have suffered will then be noticed; and the reader, having been made acquainted with the nature and relations of the beds, will be ready to understand the effect that each will have on the form of the ground, which subject will be treated of afterwards.



## CHAPTER 2. UNDERGROUND PLAIN OF OLDER ROCKS.

One of the most interesting questions in English geology has been as to what formations would be found deep underground, beneath the Valley of the Thames, more especially at and near London, and beneath neighbouring tracts. The progress of our knowledge too, on this subject, has come mostly by unexpected steps, sudden flashes of light as it were, through work done for a very different purpose: indeed all actual proof in the London Basin (at the time this was written) is from borings made in search of deep-seated water, which, whilst generally unsuccessful from that point of view, have made certain what before was only theory, and have given us much definite knowledge.

The only such work made as a scientific experiment, the Sub-Wealden Boring (far beyond our district) failed to reach below Jurassic rocks, though proving their presence in great force, where no one knew before what rocks might underlie those of Cretaceous age. This will not long stand alone however, as another experimental boring is now being made at Dover, a site much more likely to lead to the discovery of old rocks than that near Battle.

It is to be hoped that other like borings may be made, until we are able to roughly map out the range of the various formations beneath the Gault, and to know whether productive Coal Measures occur in the South East of England.

At the risk of some slight repetition it may be well firstly to give a history of the speculations and observed facts, and then to notice the formations proved, in their chronological order.

### HISTORICAL REVIEW OF THE SUBJECT, ESPECIALLY AS REGARDS THE QUESTION OF COAL UNDER THE LONDON DISTRICT.

The first definite reference to the possible uprise of older rocks underground in south-eastern England may be found in an essay by SIR H. T. DE LA BECHE, in one of the earliest publications of the Geological Survey, where the following remarks occur:—

“Though we might suspect that the coal measures, amid their undulations, might bring in other patches of profitable coal beds, beneath the lias and oolite towards Bath [from the west] . . . it might as easily happen that the general crumpling of the older rocks brought up portions of carboniferous limestone.” . . .

“From the movement of the older rocks many a mass of coal measures may be buried beneath the oolites and cretaceous rocks on the east, the remains of a great sheet of these accumulations, connecting the districts we have noticed [the Mendip Hills, &c.] with those of Central England and of Belgium, rolled about and partially denuded prior to the deposit of the new red sandstone.”\*

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\* Memoirs of the Geological Survey, vol. i. p. 214 (1846).

Considering therefore the absence of all direct evidence as to what beds occurred beneath the Chalk under London, it is not to be wondered at that, in 1851, PROF. PRESTWICH, arguing from the persistent outcrop of the Lower Greensand on the south, and the nearly persistent one on the north, and from the thickness of that formation, inferred its extension underground, and advised that borings should be made to reach it, and to get water from it. Seeing the regular sequence of the Cretaceous formations along the outcrop, it was natural to expect a like regularity underground.

Although knowledge gained since the publication of Prof. Prestwich's book (which is a great store of information as to the London Basin and the bordering Cretaceous tracts) has shown that the Lower Greensand thins out under London, yet it is instructive to note the accuracy of the conclusion to which Prof. Prestwich came as to the probable thickness of the beds above it, all of which occur in due order. He remarks that probably the Lower Greensand, or, as we should now say, the base of the Gault, would be reached "at a depth not exceeding 1,000 to 1,100 feet beneath London."\* Since those words were written, deep borings in and near London have reached the horizon in question. Of these one, in the middle of London (Meux's), gives the figures 1,002, and another, in the northern suburbs (Kentish Town), gains the figures 1,113; this being on higher ground, where the Tertiary beds are thick, and therefore just outside the tract to which reference was made. Moreover, at Crossness, beyond the south-eastern suburbs, the depth in question is 1,008, and at Richmond, where again the Tertiary beds are thick, it is 1,142. All the other deep borings which reach from the Tertiary beds to the base of the Gault (see pp. 42, 43) agree, according to the thickness of the Tertiary beds at each.

The thickness, 650 feet, assigned to the Chalk is singularly correct, especially when we remember that our author tells us that then "the greatest depth to which the chalk has been pierced under London is 300 feet." That given to the Gault, 150 feet, is also, at all events, a marvellously good guess. After writing this, I found that PROF. JUDD had already drawn attention to the accuracy of Prof. Prestwich's estimate of the thickness of the Chalk, Upper Greensand, and Gault.†

In 1852 M. MEUGY remarked that there was a great depression in Western Belgium and the North of France, which continues underground towards London, and that if coal-basins exist, as is not impossible, they might come near the southern border of this depression near Lille, and tie on, more or less directly, with the Coal Measures that outcrop in England.‡

\* A Geological Inquiry respecting the Water-bearing Strata of the Country around London . . . . . 8°. Lond., p. 142.

† *Nature*, vol. xvi. pp. 2, 3 (1877).

‡ *Essai de Géologie pratique sur la Flandre Française*, p. 76, quoted in the "Report of the Commissioners appointed to inquire into the several Matters relating to Coal in the United Kingdom," p. 148, Fol. Lond. 1871.

In May 1855 MR. GODWIN-AUSTEN read a paper before the Geological Society, in which, from a careful study of the geological phenomena of Belgium and of the West of England, he inferred that the axis of the Ardennes, in the former country, was the same as that of our Mendip Hills, and that these two outcropping parts of a long line of elevation of old rocks were connected by an underground ridge of the same, hidden by the mass of overlying and unconformable Secondary rocks.

To use MR. GODWIN-AUSTEN'S own words, "The depression of the Thames Valley represents, and is physically a continuation of, that which, extending from Valenciennes by Douai, Bethune, Therouanne, and thence to Calais, includes the great coal-trough of those countries," and he infers "that at an early time a line of disturbed surface was produced, having a general E. and W. direction, and which, traversing a portion of the area of the coal-growths, has placed all the members of that series along its course either at or near the present surface," and that "we have strong *à priori* reasons for supposing that the course of a band of coal-measures coincides with, and may some day be reached, along the line of the valley of the Thames, while some of the deeper-seated coal, as well as certain overlying and limited basins, may occur along and beneath some of the longitudinal folds of the Wealden denudation."\*

Before this remarkable paper was printed the boring of the Kentish Town well (see Well-sections) almost established the soundness of the author's reasoning, which was afterwards still more strongly confirmed by the boring at Harwich, in which a black slaty rock, of Carboniferous age, was found below the Gault. There are specimens of this rock in the Geological Museum at Jermyn Street.

In describing the former of these sections PROF. PRESTWICH noticed that instead of the loose sand of the Lower Greensand being found next beneath the Gault, there is a set of red clays and sandstones, etc. He asked, "Do these red beds form an exceptional condition of the base of the Gault? Are they local beds of the Lower Greensand? Do they belong to the mottled clays and sandstones of the Wealden? Or are they to be placed with the New Red Sandstone?", and he went on to say that "the Lower Greensand crops out with so much regularity both to the north and south of London, and skirts the Gault so continuously, that from a surface-examination of the ground there could be no apparent reason for supposing that the same deposit was not continuous underground and would not be met with beneath London. I must confess that I never contemplated the probability of any break in the order of superposition; but although it may prove that my anticipations were wrong, still I would observe that geology had nevertheless indicated the possibility of other conditions;" for Mr. Godwin-

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\* *Quart. Journ. Geol. Soc.*, vol. xii. pp. 71, 73. (1856.)

Austen, taking a wider field of observation . . . . came to the remarkable conclusion . . . . that the axis of the Ardennes was prolonged under the cretaceous series of the south of England.\*

In a later paper PROF. PRESTWICH described the deep section at Harwich, adding that "the evidence which we have now obtained from the boring at Harwich, combined with that of the Calais boring, is corroborative, and of such weight, that I do not hesitate to modify materially my former opinion of the continuous range of the Lower Greensand under London, and to adopt in great part Mr. Godwin-Austen's . . . hypothesis of an extension of an underground tract of the older rocks . . . . . Before the result of the Kentish Town well was known Mr. Godwin-Austen had arrived at the conclusion that a tract of old rocks underlies the Wealden; but he probably was as little prepared as I was for so remarkable a confirmation of his hypothesis as that furnished by the well at Kentish Town, as there, not only were all the Oolitic series wanting, but the Lower Greensand itself was absent. I fear, therefore, that there is, under the central part, at all events, of the London Tertiary area, a tract or ridge of the older rocks immediately underlying the Chalk and Gault, on different portions of which the three wells of Calais, London, and Harwich have touched, the one on the Carboniferous series, the other on the New Red Sandstone, and the last on some slate rock." He then asks "what was the size of the old palæozoic land—was it a ridge, with breaks in it at intervals, or a broad tract? The first is, I think, the more probable."†

Two years later my colleague PROF. HULL, in a paper "On the South-easterly Attenuation of the Lower Secondary Formations,"‡ made the following remarks:—"Adopting the theory of Mr. Austen regarding the extension of the Palæozoic axis of elevation under the Thames Valley, I do not, however, consider that the entire absence of all the intervening formations between the Great Oolite and the Coal-measures is to be attributed altogether to the presence of this old coast-line . . . all these formations decrease in thickness, as they approach the south-east of England, from the failure of sediment."

Treating of the "Upper Zone of the Great Oolite," he says "from its continuity over an area extending at least from Somersetshire to Lincolnshire, combined with the fact that it furnishes no evidence of a tendency to thin away towards the south-east, I am inclined to think that this subdivision extends as far as the Palæozoic barrier of the Thames Valley," a conclusion strengthened by the discovery, many years afterwards, of Jurassic rock of about that age in the borings at Meux's, at Richmond, and at Streatham (see post).

Our author concludes "that there probably exists a tract of Coal-measures stretching from the southern borders of the Stafford-

\* *Quart. Journ. Geol. Soc.*, vol. xii. p. 9. (1856.)

† *Quart. Journ. Geol. Soc.*, vol. xiv. pp. 251, 252. (1858.)

‡ *Quart. Journ. Geol. Soc.*, vol. xvi. p. 63. (1860.) Pages quoted 64, 73, 80.

shire and Warwickshire Coal-fields towards the Thames Valley, as previously surmised by Mr. Godwin-Austen, but there is reason to fear that the whole formation becomes debased and less likely to contain valuable beds of coal."

The next year PROF. HULL noticed that the Coal Measures of this island thin away from N.W. to S.E.; and he has inferred that they are not likely to occur in the south-eastern part of England, where he thinks that the Secondary formations are more likely to be underlain by still older rocks.\* By some slip, in Fig. 17 of the book referred to, (repeated in later Editions) Silurian rocks are shown as next underlying the Cretaceous beds at Harwich.

Strange to say no ideal section, illustrating the break in continuity of the beds below the Gault under London, appeared until 1864, when a short sketch of the subject was given as an Appendix "On the Likelihood of there being an Underground Ridge of Older Rocks along the Valley of the Thames" in what may be called the remote ancestor of the present Memoir.† The figure then published has done much duty since, having been reproduced in two other Geological Survey Memoirs,‡ as well as in various publications.

The next paper referring to the subject was by SIR R. MURCHISON, who came to the conclusion "that no productive coal-measures can reasonably be looked for in Essex, Kent, Sussex, Middlesex, Herts, Hants, Bucks, Oxfordshire, Suffolk, Norfolk, and the eastern counties, from Yorkshire southwards" [implying the addition of Lincolnshire], to which further on he adds Wilts, and Surrey. He remarked that, judging "from the gradual deterioration and extinction of the coal-beds [of Belgium and northern France] as they approach the French side of the Channel, I hold that there can be no reason to hope that better conditions can be looked for throughout the southern counties of England."

"Looking however to the well-ascertained data that the secondary rocks of the western and central parts of England . . . the Trias, Lias, and Oolites, thin out in their extension to the south-east . . . still it is by no means improbable that the part of the oolitic series which appears in the cliffs north of Boulogne may be persistent under the cretaceous and wealden rocks of Sussex and Kent. But the question is What will the fundamental rock prove to be in these districts if it should ever be searched for? Reasoning from such data and the visible outcrops in the Boulonnais, my inference is that, if not in part Jurassic, they will probably prove to be a thin band of carboniferous limestone without any productive coal, or more probably Devonian rock only. So far, then, I agree with Mr. Godwin-Austen as to palæozoic rocks (but unproductive of coal)

\* *The Coal-fields of Great Britain*, Ed. 2, p. 250, &c. 1861, and later Editions.

† "The Geology of Parts of Middlesex," etc., pp. 106-108.

‡ "The Geology of the London Basin" (vol. iv.) 1872, in which the Appendix was reproduced, and "Guide to the Geology of London," Eds. 1 and 2. (1875.) Ed. 3. (1880.) Altered in Ed. 4. (1884.)

being possibly found in the south-east of England.”\* When however our author says of the occurrence of “lower carboniferous limestone” in the Harwich boring, “This fact shows indeed conclusively, that the great Belgian coal-field does not extend eastward to England, though the older rocks on which it rests are persistent into our country,” I fail to follow his reasoning; that fact seems to me to prove only that the extension in question does not take place very near Harwich.

The same year SIR W. W. SMYTH, after a short description of the occurrence of Coal Measures under Cretaceous beds in the north of France, said “A comparison of these features with those exhibited on the flanks of the Mendip hills, and an observation of the underground course of the sharp trough of French coal strata . . . inclines us to the speculation that the palæozoic rocks may be continuous from the Severn to the Rhine.”†

In 1870 PROF. HULL expressed his agreement with Sir R. Murchison, in holding that “little coal was to be expected to remain under the Cretaceous rocks.”‡

In 1871 was published the “Report of the Commissioners appointed to inquire into the several matters relating to Coal,” in which full consideration was given to our subject, especially as relates to coal,§ and the opinions of geologists were noticed. No new facts however had come to light since the Kentish Town and Harwich borings; but PROF. PRESTWICH for the first time suggests that the bottom beds of the former “should probably be referred to the Old Red Sandstone” (p. 156). He controverts the conclusions of SIR R. MURCHISON, as follows:—“The coal measures, it is true, thin out in one sense as they range west from Valenciennes, but it is in consequence of their denudation before the deposition of the secondary rocks, and not from any original dying out of the measures or approach to old shore lines. The component strata retain, as well as we can ascertain, their ordinary dimensions throughout” (p. 157), and he holds “that the thinning out of the coal measures towards Calais is due to denudation, and not to any approach to the original limits of the coal measures and thinning out of the coal seams, and consequently that should the coal measures again set in to the westward of Calais [that is in England] they would be found equal in productiveness with the great coalfield of the north of France and of Belgium” (p. 158).

Another important point is then considered:—“It is well known that many productive fields become unproductive in certain direc-

\* *Rep. Brit. Assoc.* 1866. *Sections*, pp. 58–60. (1867.)

† A Treatise on Coal and Coal Mining, *Lond.* 1867, p. 78. Repeated in 5 other editions.

‡ *Proc. Roy. Soc.*, vol. xix., no. 125, p. 228.

§ *Fol. Lond.* Report of Committee D. appointed To inquire into the Probability of Finding Coal under . . . superincumbent Strata; vol. i., p. 118, “Report on the Probabilities of finding Coal in the South of England,” by J. PRESTWICH, pp. 146–165. Evidence &c., vol. ii., pp. 414, 424–437, 441–443, 448, 449, 493, 494, 498. (R. A. C. GODWIN-AUSTEN, SIR R. I. MURCHISON, PROF. E. HULL, H. W. BRISTOW, and PROF. J. PHILLIPS.)

tions . . . . . This decrease of coal beds seems dependent on the distance from original land surfaces. Everywhere along the old tract of Carboniferous and Devonian rocks, extending from Westphalia to South Wales, there appears to have been an old growth of coal-producing vegetation of great luxuriance and persistence. Everywhere along the immediate flanks of the great axis traversing that old tract we find rich and productive measures, however much they may deteriorate as they recede from that line; and there is no reason to believe but that we should find the same productiveness along the flanks of the same underground ridge, although at a distance of 20 to 30 miles from it a falling off might possibly be found. On these grounds we believe that the Coal Measures, should they exist under the Secondary rocks of the south of England, would be found in full force and in full productiveness."

Prof. Hull's opinion as to the thinning of the English Coal Measures from north to south is then argued against, except as of local occurrence, and therefore probably not affecting so distant a district as the Valley of the Thames; and it is pointed out that "we should have to take into consideration, as the Belgian coal measures, cut off near Calais, are there in full force, how far they may have extended westward before they thinned off against the old barrier land suggested by Mr. Hull," as cutting off the Coal Measures northward (p. 159).

The thinning of the Triassic and Jurassic formations from the Midland Counties towards the Thames Valley, "seems to be a well-established fact, but we have to observe, that it would equally be the case whether caused by the shoaling of the old seas against an old Cambrian and Silurian land [as thought by PROF. HULL], or by the same shoaling caused by an old land of Devonian and Carboniferous rocks. It is to this latter condition that we are disposed to attribute the effects so well noted by Mr. Hull. These Cambrian rocks, including those of Charnwood Forest, have a strike nearly S.W. and N.E., and belong to the older rock area of Wales, and not to the later one of the Ardennes. They were raised before the deposition of the Devonian rocks and Mountain Limestone, which latter repose on them unconformably. On the other hand the axis of the Ardennes and Mendips is subsequent to the coal measures, and the former area was dry land long before the latter emerged from beneath the carboniferous seas."

"From all we know of the secondary rocks south of Charnwood, we have reason to believe that that range of the older palæozoic rocks extends but very little if at all south of that district, or at least not at a depth to interfere with the presence of the coal measures, and of a great accumulation of secondary strata . . . The red sandstones found under London, and the slaty rocks under Harwich, both belong to the rocks of the Mendips and the Ardennes, and do not form part of the Charnwood Forest series; the two series belong to two different and independent systems of disturbance and elevation . . . The Charnwood Forest range was in fact merely part of a ridge of Cambrian rocks

standing in the midst of the carboniferous series, just as the Carboniferous series of the Mendips stood in the midst of the secondary formations of Somersetshire. They are the higher summits of old land of different ages."

PROF. PRESTWICH goes on to say that "the division of the coal measures into separate basins appears to be their normal condition along this great line of disturbance. The transverse ridges separating the different basins are subordinate to the great east and west axis, and so far as experience teaches us, they are never wide nor long maintained. The length of those portions of the axis included between West Pembroke and Frome, and between Calais and Dortmund, is 472 miles, and in this distance we find eight separate and distinct coalfields. The combined length of these eight coalfields is about 350 miles, leaving only about 122 miles occupied by intervening tracts of older rocks; so that nearly three quarters of the whole length is occupied by coal strata. We consider that a structure which is constant so far as the axis of disturbance can be traced aboveground is in all probability continued underground in connexion with the range of the same line of disturbance, and we see no reason why the coal strata should not occupy as great a proportionate length and breadth in the underground [S. of England] and unknown, as in the aboveground and explored area" (pp. 159, 160).

"The great original coal-trough has been broken up into separate basins, and we are not aware of any reason why any of those which may exist in the unexplored area should have been more denuded than those in the proved area. In each of the great known basins the Coal Measures exhibit approximate dimensions of thickness."

"The direction of the great underground coal trough is, we think, likely to be on a line passing through North Wilts, Oxfordshire, thence across Hertfordshire, South Essex, the north-east extremity of Kent, onwards towards Calais . . . Or in case of the anticlinal axis taking a more southern course we should look for the coal basin or basins along a line passing from Radstock, through the vale of Pewsey, and thence along the North Downs to Folkestone" (p. 162).

This Report is illustrated by a plate, which gives a "longitudinal section from Pembroke to Westphalia . . . showing the probable position of the underground coalfields lying between the Bristol and French coalfields;" a "theoretical section across the Thames Valley at London . . ."; and another "theoretical section from Harwich to near Boulogne . . ."

In the following year PROF. PRESTWICH again referred to the subject (and to the same effect as in the Report of the Coal Commission) in a Presidential Address,\* in which he says, "At those spots in the southern counties where the palæozoic rocks have been proved underground, I imagine they were raised by disturbances of a later date than the Coal-measures, and did not form

\* *Quart. Journ. Geol. Soc.*, vol. xxviii. pp. lxxv.-xc. (1872.)



part of the land-surface of the Carboniferous period." Of the "great east and west axis of disturbance," he remarks that "it took place after deposition of the Coal-measures and before the deposition of the Permian strata. Its effects, all though its range, are singularly alike. It was not so much a great mountain-elevation as a crumpling up and contortion of the strata for a breadth of many miles, and along a length of above 800 miles." Again "on further consideration, it seems to me a question whether we should not . . . assign to it a width varying from 30 to 80 miles or more."

PROF. PRESTWICH also reproduced his views in the form of a paper "On the Probable Existence of Coal Measures in the South-East of England,"\* in the sections accompanying which he showed how the "uncertain coalfields" might occur underground along a curved line between the Bristol and South Wales Coal-fields at the one end, and the Hainault and Liège Coal-fields at the other. The general conclusion is well summarised as follows:—"Of the underground prolongation of the axis of the Ardennes through the south of England there can be little doubt; nor can there be much doubt that the same great contortions of the strata which in Belgium folded alike the Coal Measures, the Mountain Limestone, Devonian, and Silurian series, and were the cause of similar folds in the same rocks of Somerset and Wales, were continued along the whole line of disturbance, and that the preservation of portions of the same great supplementary coal trough is to be looked for underground in the intermediate area, just as they exist above ground in the proved area."

In 1874 PROF. PRESTWICH considered the subject from a practical standpoint, in a paper "On the Geological Conditions affecting the Construction of a Tunnel between England and France."† He said "This ridge [of older rocks] is part of a great range extending from Westphalia to the south of Ireland, and forming a tract about 800 miles in length, with a breadth varying from 20 miles to 60 miles, whilst the main ridge is subtended to the north by a lower." These older rocks "were raised into mountain chains . . . and into continental areas with intervening seas, before the deposition of any of the Secondary strata," which "gradually spread transgressively over all the Palæozoic rocks as the old continental areas were submerged." He infers "that the crest of the . . . ridge would probably be found underground somewhere near Folkestone," and draws Section 6 in accordance with this view, showing the Lower Greensand thinning out northward of Dover, and the Wealden beds at or south of that place: the former conclusion being borne out by the Dover boring, which however gives the Wealden beds a further extension northward, an extension of which he saw the possibility. In conclusion Prof. Prestwich says of the underground range of old rocks "that it offers the

\* *Pop. Sci. Rev.*, vol. xi. pp. 225-243, pl. lxxxv. (1872.)

† *Proc. Inst. Civ. Eng.*, vol. xxxvii. p. 110, pls. 8, 9.

conditions most favourable for the secure construction of a submarine tunnel."

It was not until 1877 that any further light was thrown on the question; but then the boring at Meux's Brewery, at the corner of Tottenham Court Road and New Oxford Street, showed that, in that nearly central part of London, rocks older than Carboniferous occurred at a depth of less than 1,100 feet, as was first announced by MR. R. ETHERIDGE in the *Times* of May 16, where he notes "the sudden . . . change from the beds of lower green sand, which lie horizontally, to those of mottled red and green . . . micaceous shales, which . . . dip 30°," and concludes that the latter are "upper Devonian or Eifelian rather than British type." A mistake was made, however, in classing the next overlying deposit as Lower Greensand (see *post*).

MR. GODWIN-AUSTEN did not long delay drawing attention to "the geological significance of the boring,"\* in a short paper read to the British Association. He inferred, from the fact that the Devonian beds have a fairly high dip, and from the probability that their trend is east and west, that higher beds are likely to come on northward or southward, and "that London just overlies the edge of a great Coal-field, and the probability was that the Coal-field was to the north," an opinion which however was changed two years later.

In the same year it was noted that the second boring at Crossness, near Erith, had "passed through the Gault, and touched a reddish clay, much like New Red Marl."†

In 1878 PROF. PRESTWICH published a detailed account of Meux's well and of the Crossness boring, with remarks "on the probable range of the Lower Greensand and Palæozoic Rocks under London.‡ In this paper the author gives his reason for referring the red beds of the Kentish Town boring to the Old Red Sandstone. The specimens "agreed closely with the Mendip beds [Old Red] in lithological characters, whereas there was, on the whole, a want of agreement with the Permian or Triassic series."

The red beds of Crossness are taken to be of the same age as those of Kentish Town.

"The value of the . . . determination [of Devonian rocks] consists in the fact that in the range of the Carboniferous series through Belgium and the north of France they are everywhere accompanied, on the same strike, by Devonian strata, and the latter strata are constantly brought by great faults and flexures into juxtaposition with the Coal-measures."

There is no need to refer to the conclusions come to from the presumed absence of Jurassic rocks and the presence of Lower Greensand here, as these have been vitiated by the discovery that the beds next below the Gault are Jurassic and not Cretaceous

\* *Geol. Mag.* dec. ii., vol. iv. pp. 474, 475. (1877.)

† *Soc. Med. Officers Health. Ann. Rep.* 1876-77, p. 21. (1877.)

‡ *Quart. Journ. Geol. Soc.*, vol. xxxiv. pp. 902-918.

(see *post*) ; but the author's general conclusion may be given in his own words : " while there is every reason to hope that, on the south of London, we may yet find in the *Lower Greensand*, beneath the Tertiary strata and Chalk, a source of large and valuable water-supply, . . . there is strong reason to believe in the probability of the discovery to the north of London of *Carboniferous strata*, including possibly productive Coal-measures, under the same Cretaceous formations . . . the Palæozoic strata are so disturbed and folded that neither the dip nor the relative position of the Devonian beds afford any certain guide to the position of the Carboniferous trough."

It is a little curious that the finding of four specimens of a Jurassic species of *Thecidium*, a genus rare in the Lower Greensand, led MR. C. MOORE to infer a greater extension of the species rather than to question the identification of the formation,\* especially considering the markedly oolitic structure of the limestone, which is unlike that of any Lower Greensand.

The same year M. DEWALQUE† said that " the supposition that the dip of these Upper Devonian beds is to the south, and that they belong to the extension of our [Belgian] northern basin is that which is the most probable. The coal formation may therefore occur at a short distance south of London, and at a workable depth. . . . Starting from the supposition that our (Belgian) old strata are prolonged westward into England, and from the fact that Upper Devonian strata occur under London, we are led to admit that the band of Silurian slates of the Ostende boring must pass north of London." It is to the paper next to be noticed that I am indebted for the above translation.

In 1879, in a paper " On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-East of England," MR. GODWIN-AUSTEN alluded to the discovery of Silurian rocks, beneath the Gault, at Ware (see p. 21), as bearing out M. DEWALQUE's inference, and concluded therefore that the Devonian beds, at Meux's, probably dip southward, so that, allowing fairly for Carboniferous Limestone between, " the lower members of the true Coal-measure formation may be fairly expected to occur " no great distance (about 1,200 feet is suggested) " south from the corner of Tottenham Court Road and Oxford Street, the upper, or productive Coal-measure, still further to the south.‡

Considering how much these beds may be affected by rolls, or cut off by Triassic or Jurassic deposits (not suspected at the time) there is great risk in prediction.

This paper is accompanied by a geological map, " to illustrate the evidence in support of the continuity of productive Coal measures beneath the S.E. Counties of England."

\* *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 919.

† *Ann. Soc. géol. Belg.*, t. v. pp. lxx.-lxvii. (1878.)

‡ *Rep. Brit. Assoc. for 1879*, pp. 227-229, and *Nature*, vol. xx., No. 518, p. 547 (text only, and slightly different).

The same author, in the "Report of a Committee . . . . . appointed for the purpose of assisting the Kentish Boring Exploration," (written in 1878, but not published until the next year), remarks that the Devonian is simply an early stage of a series which passed on, through the Carboniferous Limestone to the Coal Measures, and that therefore the last may be expected to follow in due order, north or south, as the case may be.\*

The same year DR. C. BARROIS, in a notice of Prof. Prestwich's paper on the section at Meux's,† referred the Devonian rocks there to the horizon of the Schists of Famenne (in northern France).

In this year our knowledge of underground rocks received a great addition, MR. ETHERIDGE‡ being enabled to announce the discovery, in a boring at Ware, "of one of the oldest formations in the British Islands immediately beneath the Gault and at the depth of 800 feet . . . the Upper Silurian rocks (the Wenlock shale), richly fossiliferous, dipping at an angle of 40°." It follows therefore that these beds, older than any before found in the district, are at a less distance from the surface than the Devonian or the red beds of earlier borings.

The same author also contributed a paper on "the Position of the Silurian, Devonian, and Carboniferous Rocks in the London Area,"§ in which the occurrence of Upper Devonian rocks beneath the Gault at Cheshunt (Turnford) was announced, and a general account of the question of underground older rocks was given.

Reasoning from the occurrence of Devonian rocks at Meux's and Turnford, and of Silurian at Ware, MR. ETHERIDGE says "We are thus justified in stating that the underground region between Messrs. Meux's, at Tottenham Court Road, and Ware—a distance of 24 miles—is occupied by the Upper Silurian, and probably the Lower, Middle, and Upper Devonian rocks, which may be rolled and folded." But this wholly leaves out of consideration the possibility, or one may say the probability, that the rolls and folds may in some cases result in bringing in masses of newer beds. It seems very unlikely that the Devonian rocks should have sole occupation over so long a distance as is implied, unless their dip is low; and in the two cases of their occurrence the dip is 30°, or more. The red beds at Kentish Town can hardly be brought in as evidence, for whether they are of Devonian age, or newer, is merely a matter of opinion. One is disposed therefore to question the conclusion that "it would now appear from recent research that there is little chance of any rocks younger than the Devonian occurring due north of London," and to dissent from the statement that "it is clear that all the stratified rocks between the Silurian, Devonian, and the Gault are wanting:" it wants more than three borings (one at either end of a line 24 miles long

\* *Rep. Brit. Assoc.*, 1878, pp. 380–382. (1879.)

† *Ann. Soc. Géol. Nord*, t. vi. pp. 96–100. (1879.)

‡ *Times*, May 19, Reprinted, with an additional Note, in *Geol. Mag.*, dec. vol. vi. pp. 286–288. (1879.)

§ *Pop. Sci. Rev.* n. ser. vol. iii. pp. 279–296, pl. vii. (1879.)

and the other somewhere between) to make such an inference safe.

PROF. DEWALQUE also alluded to the Ware discovery, reprinting the list of fossils.\*

The next year MR. J. HOPKINSON'S paper "On the Recent Discovery of Silurian Rocks in Hertfordshire"† gave a general account of the subject, referring especially to the Ware boring, and adopting Mr. Etheridge's inference to the effect that "it is now seen that it would be useless to search for coal (in the London Basin) north of London," which, as above noted, should be taken with the proverbial grain of salt, because it rests on a dangerous assumption.

The same year (1880) it was remarked, in a Geological Survey Memoir‡ "that there is a strong reason against the classification of the bottom beds at Kentish Town and Crossness with the Old Red Sandstone, which seems to have escaped notice. Having the series unmistakably present in the Devonian type at Chess-hunt and at Meux's, it would be strange indeed were it to occur in its wholly distinct Old Red type at Kentish Town, between those two places, and at Crossness, not very many miles from the latter of them! . . . no such thing is known to occur anywhere; the two types of what is generally taken to be one great geological system being limited to separate districts, and not occurring together." See however WOODWARD (p. 27).

"The general tendency of the known facts is therefore to show that, whilst northwards from London older rocks rise up, for many miles at least, south-eastwards, on the other hand, newer rocks come on above. The inference from this is of course that it is in the latter direction we should, in the first place, expect to find Carboniferous rocks of some sort, if not actual Coal Measures. That disturbances of the beds may bring in such rocks elsewhere is of course likely; but we have no evidence of the whereabouts of the lines of disturbance that doubtlessly occur."

The next year PROF. HULL treated of the "possible occurrence of coal under the South of England,"§ some of the deep borings having been made since the appearance of the third edition of his book. The statement based on the evidence of these (p. 353) that "whatever . . . may be the nature of the Palæozoic strata at some distance to the south of the Thames Valley near London, no doubt can remain that the Coal-formation is absent under London itself . . . we must look to the tracts lying south of the Thames Valley as the possible areas of concealed Coal-fields" seems too strongly worded. That Coal Measures have not been found in the few borings as yet made does not prove that they do not occur anywhere under London:

\* *Ann. Soc. géol. Belg.*, t. vi. pp. cxxxvii., cxxxviii. (1879.)

† *Trans. Watford Nat. Hist. Soc.*, vol. ii., pt. 7, pp. 241-248, pl. ii. (1880.)

‡ *Guide to the Geology of London.* . . . Ed. 3, p. 21. Repeated in Ed. 4 (1884).

§ *The Coal-fields of Great Britain.* Ed. 4, pp. 349-356. (1881.)

indeed a different conclusion has been drawn by other geologists, as may be seen from what has gone before. "As bearing upon this view, the discovery of true Coal-measures at Burford, in Oxfordshire, at 1184 feet from the surface, is exceedingly interesting," for Burford, though far away from our district, is north of the Thames Valley, being indeed in about the same latitude as Ware; and the line spoken of by our author, from the centre of the South Wales Coalfield through that of the Forest of Dean to Burford, would, if produced further eastward, go through central Hertfordshire and Essex.

In the section through the London Basin (p. 354) constructed according to his theory PROF. HULL gives the underground old rocks a continuous southerly dip, varied only by slight puckerings in the southern part, from beyond the escarpment of the Lower Greensand on the north to some way into the Wealden tract on the south, a distance described as about 65 miles, which does not err by excess. What the thickness of the series shown, from Lower Silurian (or say Cambrian) up to say the top of the Middle Carboniferous would be is left to the reader to calculate, taking the dip at  $30^{\circ}$  (the lowest observed). It would certainly be far beyond anything known at the surface.

Moreover I believe that no such thing is known, in England, as an outcrop of these old rocks, in continuous succession and with constant dip, for a breadth of anything near 65 miles. We must reason from the known to the unknown, and should not expect such rocks to behave differently underground from what they do at the surface.

The same year MR. ETHERIDGE again took up the subject, in discussing "the Extension of the Older or Palæozoic Rocks below the Newer or Secondary Formations," at the end of his Presidential Address to the Geological Society,\* and gave S.E. as the direction of dip of the Silurian beds at Ware and of the Devonian beds at Cheshunt and London. He said that "We can hardly now doubt the extension of the Burford [Oxfordshire] Coal-measures, in all probability terminating against the Silurian or Devonian series in the Ware region, at Turnford, and near London." The assumption that there is a constant dip of the older rocks in one direction from Ware to London is again brought forward.

In 1882 PROF. JUDD gave a short general account of "the Possibility of finding workable coal-seams under the London area,"† remarking that "the evidence obtained from these borings [Meux's &c.] proves that the rocks forming the old Palæozoic ridge are bent into a series of east and west folds, and among these folds it is highly probable that Coal-measure strata will be found. . . The coal-basins, if they exist on this Palæozoic ridge, are probably long and narrow . . like those of Belgium

\* *Quart. Journ. Geol. Soc.*, vol. xxxvii.; *Proc.*, pp. 227-235. (1861.)

† *Nature*, vol. xxv., no. 640, pp. 311-313, no. 642, p. 361.

and Northern France, having their longer axes directed from east to west."

"The discovery of Upper Devonian strata, both at Turnford [Cheshunt] and at Tottenham Court Road, in both cases dipping at high angles, lends not a little support to the view that a trough of Carboniferous strata may exist between those two localities."

This year M. A. FIRKET, in a paper on the possible existence of Coal in the Environs of London,\* gave a resumé of the work of geologists on this question, and speculated on the probability of the continuation in the South-east of England of the great disturbance known as the "Faille eifellienne," the "Faille du Midi," or the "Grande Faille" (the Eifellian or Great Fault), which, from its comparatively slight inclination to the south, has sometimes caused the superposition of older beds on the Coal Measures in northern France. He concluded that the westerly underground extension of the Franco-Belgian coal-basin is south of London; whilst it is not impossible that another underground coal-basin may exist northward of Ware; and he suggested that trials should be made in Lambeth and Southwark, and to the south.

Our next and, as regards pre-Jurassic rocks, our latest information came in 1884, in PROF. JUDD's paper "On the Nature and Relations of the Jurassic Deposits which underlie London,"† the text, and indeed the origin, of which was the deep boring at Richmond. In this work the base of the Gault was reached at a depth of 1,140 feet, below which were found thin and chiefly calcareous beds, which may be of Neocomian age. These were succeeded by Great Oolite, chiefly limestone, and on comparing the last with the oolitic limestones beneath the Gault at Meux's well, it was found that a mistake had been made in classifying the latter as Lower Greensand, and that they belonged to the same formation as the lithologically similar beds at Richmond. This is the first recognition of Jurassic rocks under the London Basin.

Beneath the Jurassic beds a thick set of sandstones and marls, mostly red, was found, and was classed by PROF. JUDD as Poikilitic (a term that is equivalent to the original meaning of "New Red," including Trias and Permian). He remarked (p. 751) that "the possibly high angle of dip of these strata . . . may appear, at first sight, to afford an argument in favour of the Palæozoic age of the rocks . . . On the other hand, the presence of disseminated particles of galena, and the considerable proportion of chloride of sodium in the water obtained from these red rocks . . . are obvious points of analogy with the Triassic strata."

From the absence of Rhætic, of Liassic, and of Inferior Oolite beds in the Boulonnais, where the Great Oolite rests on far older formations, and in the metropolitan area (as far as our borings show)

\* *Rev. Univ. Mines*, 2 ser., t. xii. pp. 456-474. (1882.)

† *Quart. Journ. Geol. Soc.*, vol. xl. pp. 724-764.

PROF. JUDD concluded (pp. 754, 755) "that these districts and probably the whole area between them constituted dry land during the Rhætic, Liassic, and Bajocian periods. And this conclusion is confirmed by the manner in which the well-developed strata of those ages in the West of England and in Normandy thin away and disappear as they are traced towards the east."

"But about the commencement of the Great-Oolite period the great ridge of Palæozoic rocks occupying what is now the south-east of England and the north of France began to be submerged, and the strata now for the first time described were then deposited

"The Great-Oolite strata which were thus deposited on the southern flanks of the great Palæozoic axis probably, however, never extended over the northern half of that axis. This is shown by the evidence of littoral, and even of estuarine and terrestrial conditions, in the Great-Oolite strata found at Meux's Brewery. At this period there appears to have been an extensive tract of dry land lying to the north of the Great-Oolite sea which covered what is now the south-east of England and the north-east of France. From this land were borne pebbles of various hard rocks, of coal-measure sandstone, and of coal, which we now find in the bands lying at the base and the summit of the Great-Oolite strata at Richmond."

"That the submergence of the Palæozoic ridge, which took place during the Great-Oolite epoch, was continued during the period of the Middle Oolites," is evidenced by the occurrence in the Lower Greensand of Surrey of waterworn fossils of both Lower and Middle Oolite age (as pointed out by GODWIN-AUSTEN) but the latter in greater number. "Taking these facts in connexion with that of the presence of Middle Oolites under the Weald, as revealed in the boring at Battle . . . we are led to the conclusion that the Middle-Oolite strata originally overlapped those of Great-Oolite age, and probably extended right across the Palæozoic ridge. Thus we should conclude that during the period of the Middle Oolite the great Palæozoic axis was completely submerged, and that the deep-water Oxfordian Clays of the north of France and of central England were deposited in a continuous sea," a conclusion somewhat borne out by the finding of Oxford Clay in the Chatham boring (see *post*). Nevertheless the absence of this clay in all the deep borings in and near London is somewhat against this view, as it compels us to assume a complete denudation of those beds over a large tract, as PROF. JUDD does (p. 756).

The bearings of the new facts brought to light by the Richmond boring on the question of the existence of coal under the London area are discussed, and it is inferred (pp. 758, 759) that the "Oolitic strata probably increase in thickness as we proceed southwards" and consequently "that further to the south the distance of the Palæozoic ridge from the surface would be still greater," though perhaps "unequal elevation and denudation in pre-Cretaceous times might bring about a set of conditions



which, if known, would greatly tend to modify the above conclusions."

Our author continues thus (p. 760):—"All who have paid much attention to the subject have been convinced that coal-seams, if found under London, would probably prove to be, as a whole or in part, of the anthracitic variety. This being the case it is interesting to notice that in the junction-beds above and below the Great Oolite at Richmond, fragments of anthracite mingled with pebbles of Coal-measure sandstone and other hard rocks from the Palæozoic ridge were found in considerable abundance . . . . Hence we are irresistibly led to the conclusion that at the period when the Jurassic strata were being deposited, portions of the old Palæozoic ridge were above the sea-level, and that among the rocks of this old ridge were Coal-measure sandstones with seams of anthracite. That these fragments of anthracite were derived from no very distant locality may be inferred from the brittle nature of the substance."

In the discussion on this paper PROF. HUGHES raised a difficulty as to assigning a Triassic age to the red beds; namely that "nowhere else did an unconformity so marked occur between Oolitic and Trias," or in other words, beds of the former age had never been seen to rest directly on those of the latter, Liassic beds everywhere coming in between the two.

However, PROF. GOSSELET, M. A. SIX, and DR. C. BARROIS (the last of whom gave an analysis of Prof. Judd's paper) all conclude, from specimens, that the red beds are Triassic.\*

The same year the occurrence of Oxford Clay next beneath thin Lower Greensand at Chatham, was announced in a Geological Survey publication,† proving the thinning-out of the great Wealden Series no great distance from the outcrop on the south.

On April 22, 1884, there happened a most unusual event, the Essex Earthquake, which did much damage to buildings, etc., over a tract some miles southward from Colchester, being indeed the the most powerful occurrence of the sort, in these islands, for four centuries. Naturally it occurred to geologists that the shock might have been propagated from the Colchester district along the underground, older, harder, and better-conducting rocks to those distant places where it was recorded, and my colleague MR. W. TOPLEY‡ remarked that "one of the most interesting questions connected with the recent earthquake is to ascertain whether there be any relation between the known range of these older rocks and the range of the earthquake over areas far distant from its central spot," and he concluded that "the far distant places . . . make it probable that some such connexion exists."

"It seems therefore likely that the wider and more general range of the earthquake is connected with the range of the Palæozoic rocks." The section given from Bristol to Harwich,

\* *Ann. Soc. géol. Nord.*, t. xi. p. 144. (1884.)

† *Guide to the Geology of London* . . . . Ed. 4, p. 19. (1884.)

‡ *Nature*, vol. xxx., no. 757, p. 61, and no. 759, p. 84. (1884.)

has one error of detail, in making the Chalk rest directly on the Palæozoic rocks from London eastward.

The "Propagation of the Shock along the Older Rocks" was treated of fully in the following year, in pp. 172-183 of that most valuable work the "Report on the East Anglian Earthquake," by PROF. R. MELDOLA and W. WHITE,\* to which the reader is referred. The authors think "that it may be safely concluded that the westward extension of the shock was as it were exaggerated by the spreading of the older rocks in that direction . . . ."

"The action of the older rocks in spreading the shock is apparently shown by the circumstance that all the extreme stations [of record] are either on Palæozoic formations or very near the outcrop."

The discovery of Oxford Clay at Chatham was more fully alluded to the following year, by PROF. JUDD, in his Supplementary Notes on the Deep Boring at Richmond,† in which he remarks that the evidence of the fossils, from Chatham, "is conclusive that the strata which contain them . . . belong to the middle portion of the Oxfordian, the Zone of *Ammonites bimammatus* of Oppel or the Zone of *Ammonites Lamberti* of English authors."

MR. H. B. WOODWARD has said, of the suggestion "that rocks of Old Red Sandstone and Devonian type are not likely to occur near together," that it is "opposed to what is well known in Devonshire," where sandstones and grits occur, "nowhere far removed, geographically, from rocks of Eifelian type . . . . Hence, without committing myself to any definite opinion on the subject, there appears to me no reason why rocks of Old Red Sandstone type . . . should not occur, as well as Devonian strata, under the London Basin."‡ But the question of the red marls is left.

The full description of the Chatham and other Kentish deep borings, which appeared in 1886,§ was accompanied by some "General Remarks on the Deep-seated Geology of the London Basin," (pp. 40-44), in which it was said, of Prof. Hughes' argument against the Triassic age of the red beds, noticed above, "that it applies only to the Richmond section, where the red beds are overlain by a Jurassic deposit. It does not apply to the cases of Kentish Town and Crossness, where the Gault comes next to the red beds. As, in the West of England, Cretaceous beds, overlapping the whole of the Jurassic Series (including the Lias), often rest at once on Trias, so a like thing may occur in the London Basin; and, even if the bottom-rock at Richmond should turn out to be Old Red, it does not follow that the same age must be assigned to the beds beneath the Gault in the other borings. Old Red moreover is not the only alternative in the Richmond

\* *Essex Field Club Special Memoirs*, vol. i. (1885.)

† *Quart. Journ. Geol. Soc.*, vol. xli. pp. 523-528. (1885.)

‡ *Geol. Mag.*, dec. iii. vol. iii. p. 43. (1886.)

§ *Quart. Journ. Geol. Soc.*, vol. xlii. pp. 28-48, pl. iii.

case, Carboniferous rocks being often stained red": indeed I have seen a specimen from Richmond somewhat suggestive of stained Carboniferous sandstone.

"As to the question of finding Coal Measures along the Valley of the Thames," the author says, "it seems to me that a hopeful answer is possible, or at least that a negative one cannot be given; for we know not what may be hidden under the Jurassic and possibly Triassic beds that have been found; and Upper Silurian, Devonian, and Lower Carboniferous rocks having already been found, it would be strange if the Upper Carboniferous had been wholly swept off."

The same year PROF. PRESTWICH gave a section across the London Basin, from Essenden, through London, to Caterham, showing the northerly thinning-out of the Lower Cretaceous and Jurassic beds, south of London, and the gentle northerly rise of the plain of the older rocks.\*

In a supplementary paper to that of 1886† further and fuller details were given of a boring at Dover, and it was shown that the clays beneath the thin Lower Greensand there probably belong to the Hastings Beds, which therefore have an underground range beyond that of the overlying Weald Clay. In both of these papers Dover was advocated as a good site for an experimental boring.

Whilst this Memoir was being printed MR. A. J. JUKES-BROWNE has alluded to the doubtful red beds,‡ remarking that "no thick deposit of red marl, such as forms the mass of the Keuper, has been met with in these borings [Richmond, Crossness and Kentish Town] . . . Further, the Keuper Sandstone group generally maintains a uniform character over considerable areas, whereas the characters of the strata below London vary largely . . . These variations might of course be due to the proximity of a shore-line; but, considering all the circumstances, and especially the great distance of the sites south-east of any place where Trias is known to exist, I incline to the opinion . . . that these strata belong to the Old Red Sandstone." As there is a great unconformity above our deep-seated red beds, the Lias, and sometimes the whole of the Jurassic beds, being absent, it is likely that the upper part of the Trias (supposing the presence of the formation) may have gone also; though the fact that the Keuper, or upper, division extends further than the Bunter, or lower, division, is, as my colleague seems to infer, a reason for expecting the former rather than the latter.

Lastly my former colleague MR. T. V. HOLMES has taken the subject for a Presidential Address to the Essex Field Club, especially as concerns that county, and has kindly allowed me to

\* *Geology*, vol. i., plate opp. p. 166. (1886.)

† *Quart. Journ. Geol. Soc.*, vol. xliii. pp. 197-205. (1887.)

‡ *The Building of the British Isles: a Study in Geographical Evolution*. 8° Lond. pp. 123, 124. (1888.)

see his MS. in advance of its appearance in print. He says, "it appears to me, looking simply at the scanty available evidence (the natural inferences from which might be seriously modified by the results of a single additional boring) that we are more entitled to expect the preservation of coal-basins north-east of Ware than south of Richmond and Chatham; along a line ranging from Ware through Bishop Stortford, Braintree and Colchester, or thereabouts." At the end of this address the author remarks that, "The great distances apart at which the outcrops of particular formations may often be seen have tended to make geologists forget the fact that, as almost all the sedimentary rocks have been formed in seas more or less shallow, the belts of ground they occupy may be of no great width, though frequently of very great length. It does not therefore follow that because the outcrop of a particular formation is traceable for hundreds of miles in a certain general direction, the subterranean belt of ground it covers in the direction of its dip need be very broad . . . Now in Dorsetshire, where the Oolitic beds above the Oxford Clay are all well shown, their average combined thickness would appear to be . . . about 1,250 feet . . . In the Boulonnais . . . their thickness is . . . about 765 feet, while at Battle [Sub-Wealden Boring] . . . it was 1,840 feet. The distance in a straight line from the Isle of Portland to Battle is about 130 miles, and from Battle to the Bas Boulonnais rather more than 50 miles. It is noteworthy, therefore, that while we meet with many hundreds of feet of Upper Oolite beds both in the east and in the west, they wholly disappear [at Chatham] only 32 miles north of the intermediate place, Battle, at which they are unusually thick."

*Postscript.*

Whilst this Memoir was passing through the press, the writer drew attention, at the Bath Meeting of the British Association, to "The Extension of the Bath Oolite under London, as shown by a Deep Boring at Streatham."\* Just before the meeting Oolitic limestone had been met with next beneath the Gault (see Well-sections, *post.*), this being the third occurrence of the Lower Oolite in a deep boring in or near London. The advisability of continuing the boring was advocated in the *Times* of October 17.

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\* Reported in various newspapers.

### CHAPTER 3. UNDERGROUND PLAIN OF OLDER ROCKS (*continued*).

#### FORMATIONS THAT HAVE BEEN FOUND BENEATH THE GAULT.

As the Ware boring was finished after the Memoir descriptive of that neighbourhood (Sheet 47) was published, and as it is not far beyond our district, we may well begin this chapter with a notice of the oldest rocks yet found in the London Basin, using that term in the wide sense, for a tract bounded by the great Chalk escarpments.

#### *Upper Silurian.*

In his first announcement of the Ware discovery MR. ETHERIDGE described these rocks simply as Wenlock Shale, richly fossiliferous; but in his second notice (see p. 21) he adds that "the facies of the fossils and the character of the rock in all its essentials are decidedly British . . . The thirty species of fossils noticed in the cores, are . . . identical with those of the Wenlock Edge, or Wren's Nest, near Dudley, and no difference can be detected in the lithological characters of the rocks." Further on he remarks that "the facies of the fossil contents of the . . . cores at Ware is not that of the Malvern or Woolhope series, or of the still nearer beds at Tortworth . . . nor can they be correlated with the Upper Silurian series of the Ardennes in Belgium, from which they essentially differ." MR. HOPKINSON, in the paper above cited (p. 22), tells us that the shale had "thin intercalated beds of limestone."

There is a large specimen of a core of this rock in the Geological Museum at Jermyn Street.

The following list of fossils is taken from Mr. Etheridge's papers, and we are told that the specimens "were obtained from a core less than three feet in length and one foot in diameter. A few corrections in nomenclature have been made by MR. G. SHARMAN.

#### *Cephalopoda.*

Orthoceras angulatum, <i>Wahl.</i>		Orthoceras, sp.
„ attenuatum, <i>Sby.</i>		

#### *Gasteropoda.*

*Euomphalus rugosus*, *Sby.*

#### *Lamellibranchiata.*

<i>Ctenodonta</i> , sp.		<i>Orthonota rigida</i> , <i>Sby.</i>
<i>Mytilus mytilimeris</i> , <i>Conr.</i>		<i>Pterinea</i> , sp.

*Brachiopoda.*

<i>Athyris</i> , sp.	<i>Rhynchonella cuneata</i> , <i>Dalm.</i> ?
<i>Atrypa reticularis</i> , <i>Linn.</i>	or <i>deffera</i> , <i>Sby.</i>
<i>Chonetes</i> , sp.	<i>Spirifera elevata</i> , <i>Dalm.</i>
<i>Crania implicata</i> , <i>Sby.</i>	„ <i>plicatella</i> , <i>Linn.</i>
<i>Cyrtia exporrecta</i> , <i>Dalm.</i>	<i>Strophomena antiquata</i> , <i>Sby.</i>
<i>Leptaena sericea</i> , <i>Sby.</i>	„ <i>depressa</i> , <i>Dalm.</i>
„ <i>transversalis</i> , <i>Dalm.</i>	(= <i>rhomboidalis</i> , <i>Wilckens</i> ).
<i>Orthis canaliculata</i> , <i>Lindst.</i>	„ <i>euglypha</i> , <i>His.</i>
„ <i>elegantula</i> , <i>Dalm.</i>	„ <i>reticulata</i> , <i>M' Coy.</i>
<i>Pentamerus galeatus</i> , <i>Dalm.</i>	<i>Whitfieldia</i> ( <i>Meristella</i> ) <i>tumida</i> , <i>Dalm.</i>
„ <i>linguifer</i> , <i>Sby.</i>	

*Crustacea.*

*Phacops caudatus*, *Brünn.*

*Annelida.*

*Tentaculites ornatus*, *Sby.*

*Echinodermata.*

<i>Periechocrinus moniliformis</i> , <i>Mill.</i>	<i>Taxocrinus</i> , sp.
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*Spongida.*

*Ischadites Koenigi*, *Murch.*

In the earlier list, in the *Geol. Mag.*, "*Streptorhynchus*, sp." also appears, probably in mistake, as the name does not occur in the later lists.

*Upper Devonian.*

PROF. PRESTWICH has described the beds of this age found in Messrs. Meux's boring, as "mottled red, purple, and greenish shales, occasionally finely micaceous, in parts very calcareous, . . with lenticular seams or thin beds of hard grey and red sandstone or quartzite, and with beds of red marl . . A good many fossils were met with from time to time in the shales,"\* and he remarked that the specimens agree with those from Devonian beds near Bethune. MR. ETHERIDGE has described them as "of the true N. Devon and N. Cornwall Devonian type—dark chocolate-coloured semi-slates," and the Turnford beds he has alluded to also as "dark chocolate-coloured Upper Devonian rocks crowded with characteristic fossils."†

There are specimens from these borings in the Museum at Jermyn Street, which show their similarity at the two sites.

Although many fossils occurred, the number of kinds identified is not large, as may be seen from the following list.

C. Cheshunt (Turnford) species from ETHERIDGE, *Quart. Journ. Geol. Soc.*, vol. xxxvii., *Proc.*, p. 234.

L. London (Meux's) from the same, and from PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 904.

*Lamellibranchiata.*

<i>Avicula damnoniensis</i> , <i>Sby.</i>	- C.	<i>Edmondia</i>	-	-	- C. L.
„ <i>texturata</i> , <i>Phil.</i>	- C.	<i>Modiola</i>	-	-	- C.
<i>Aviculopecten</i>	- C.	<i>Pterinea</i>	-	-	- C.

\* *Quart. Journ. Geol. Soc.*, vol. xxxiv. pp. 903, 904.

† *Ibid.*, vol. xxxvii., *Proc.*, pp. 232, 234.

*Brachiopoda.*

Chonetes	-	-	-	L.	Spirifera disjuncta, Sby. (=		
Orthis	-	-	-	L.	S. Verneuilli, Murch.)	-	C. L.
Rhynchonella	boloniensis?				Strophomena rhomboidalis,		
(sometimes given as R.					Wilckens	-	C.
pleurodon?)	-	-	-	L.			

Fenestella	-	-	C.	Rhodocrinus	-	-	C.
Tentaculites	-	-	C.				

*Red Rocks (Old or New Red).*

The question of the age of the various red sands, sandstones, and clays that have been found next beneath the Gault at Kentish Town, at Crossness, and at Richmond, has already been alluded to; and considering the small amount of evidence we have on this matter it seems safer to notice these beds under a heading that leaves their age an open question; for it is doubtful whether it will be settled until such beds are found either over or under Carboniferous rocks.

At Kentish Town these beds were found in great variety, partly with yellow, white, greenish, grey and mottled intercalations, as described in the account of the boring (see Well-sections), and so doubtful did their age seem that PROF. PRESTWICH at first questioned to what formation they might belong (see p. 12), concluding as follows:—"The exact state of the question remains, however, yet to be decided. No satisfactory proof of these beds belonging to the New Red Sandstone has hitherto been met with. In mineral character they certainly closely resemble the Red Marls . . . As it is well known that the Gault in some places passes into a red clay, I at first considered it possible that these strata might be the result of a like change, but the great thickness of the beds and the alternations with sandstones militate against this view." . . . Several fragments of apparently cretaceous *Ammonites* and *Belemnites* have been brought up by the auger, but it may be doubtful whether those may have fallen down the sides of the bore-hole." PROF. T. R. JONES reported that "the red clays and sands, of which I have washed and examined four or five specimens, have yielded nothing organic," and PROF. PRESTWICH added that "the boring tools seemed to indicate that the strata had a very considerable dip. It is possible however that this may arise from the laminæ of false stratification [or current-bedding] as well as from true bedding."\*

In 1872 MR. GODWIN-AUSTEN suggested that the pebble-beds of this boring might be of Lower Cretaceous age.†

\* *Quart. Journ. Geol. Soc.*, vol. xii. pp. 9-12. (1856.)

† Report of the Coal Commission, vol. ii. p. 432.

Of these beds at Crossness still less can be said. PROF. PRESTWICH has described them as "mottled red grey and greenish hard sandstones and red, slightly calcareous clays [for details see Well-sections] . . . but, owing to the small size of the bore-hole, the specimens were so fragmentary and, as in the case at Kentish Town, so much mixed with debris and fossils from the Gault and Chalk, that their determination was for a time difficult. After, however, inspecting various specimens . . . and eliminating all the sources of error, I have now no doubt of the identity of the beds with those at Kentish Town."\* From the small specimens that I have seen nothing can be added, except that there is a likeness to New Red Marl; but this is purely a lithological matter, and not of much weight, as such clayey beds occur also in the Old Red Sandstone.

Although much better specimens were got from the much larger bore-hole at Richmond, yet our doubts as to the age of the red beds were no nearer solution thereby. Details of the section are given elsewhere (Well-sections) and PROF. JUDD's general description will now be quoted.†

"The sandstones vary in colour through different shades of red to white and greenish tints. They are sometimes excessively fine-grained and very perfectly laminated, having the surfaces of the laminae covered with flakes of silvery white mica. At other times the sandstones are much coarser, so coarse indeed as almost to merit the name of grits, and their bedding is obscure. Clay-galls are found in some of the beds as well as impressions which may possibly indicate the former presence of plant-remains that have now been entirely removed. The sandstones are sometimes traversed by thin veins of calcic carbonate. Particles of galena were found . . . at a depth of 1,293 ft. 6 in."

"The clays ("marls") which alternate with these sandstones are of a dark red colour, mottled with green in blotches and spots. When brought up in solid lumps these clays are seen to be highly indurated and traversed by joints in various directions, the joints being coated with a green calcareous deposit."

"In some portions of these strata the marls and sandstones alternate in thin layers; in other portions we have a considerable thickness of marls; while sometimes the sandstones constitute tolerably thick beds." . . .

"The whole of the superincumbent Tertiary, Cretaceous, and Jurassic strata appear to be nearly horizontal . . . and it became a matter of much interest to determine if the underlying red sandstones and marls were conformable with them. Some specimens of cores showing a remarkably high dip appear at first sight to negative any such supposition. But a careful study of these apparent dips shows that they vary greatly in amount at different depths, and that therefore they are examples, not of true dip, but of oblique lamination or false-bedding. Some of the

\* *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 908.

† *Quart. Journ. Geol. Soc.*, vol. xl. pp. 749-751. (1884.)



cores, indeed, exhibit clear evidence of false-bedding." A table of the measured dips shows a variation from  $21^{\circ}$ , at the depth of 1,255 feet, to  $45^{\circ}$  at the depth of 1,365 to 1,367½ feet.

"It is worthy of remark that the most discordant dips are found in the finely laminated sandstones, in which false-bedding would be best exhibited. The cores, on the other hand, in which such marked lamination is not to be detected, give generally dips of about  $30^{\circ}$ . From these facts we may infer, with some probability, that the strata in question have a true dip of about  $30^{\circ}$ , which is often complicated and obscured by the oblique lamination. Of the *direction* of the dip no evidence could be obtained."

"It is hardly necessary to remark that these red sandstones and variegated marls have yielded no fossils. There are very marked differences . . . between these beds and those met with in the Kentish Town boring, especially in the absence of quartzites and other peculiar rocks [pebbles]."

These red beds, PROF. JUDD says, "resemble, in the most striking manner, the rocks of both the Old and the New Red Sandstones . . . Some of the beds, it is true, appear to be of a somewhat more compact and indurated texture than is usual in the rocks of those formations when exposed at the surface; but this is no more than might be anticipated when we bear in mind the great thickness of superincumbent strata which has had to be pierced before reaching them."

The facts recorded in PROF. JUDD's supplementary paper on the Richmond boring merely confirmed the above statements, the author making the following additional remark: "The lowest beds exposed in the boring are certainly much more like those of the New Red than of the Old Red. It must be remembered, too, that in Northamptonshire somewhat similar variegated strata have actually been found intercalated with the Carboniferous series."\*

There are good specimens of the Richmond beds in the Geological Museum, Jermyn Street, and some small specimens from Kentish Town and from Crossness (?). The micaceous red sandstone from the first place seems to me not a little suggestive of stained Coal Measure Sandstone.

### *Jurassic Rocks.*

The beds next beneath the Gault, in the boring at Meux's Brewery, were originally described by PROF. PRESTWICH, as follows (for details see Well-sections): "Under this [the nodule-bed at the base of the Gault], the bore-hole entered a sandy calcareous stratum of a light ash-colour, which passed into a compact light-coloured or white limestone, and then into a rock having the appearance of an oolite, being composed of fine calcareous grit in a calcareous paste. Some portions of these strata were more sandy than others, and a small quantity of mica

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\* *Quart. Journ. Geol. Soc.*, vol. xli. p. 525. (1885.)

and a few grains of chlorite were occasionally to be detected." The lower part "became grey and argillaceous."

MR. C. MOORE at the same time described the six specimens of the softer beds sent to him, from depths of 1,018 to 1,057 feet, as coarse grey marl, some samples more indurated, and most with darker granules and free oolitic concretions. Speaking of materials in these specimens derived from older rocks this author describes them as "some small irony-looking grains of quartz, several grains of what appear to be sulphate of barytes, a minute flake of carbonate of copper, and several small grains of coal . . . however small the fragments they equally imply the possibility of coal somewhere in the district."\*

Later PROF. JUDD said: "There are some very serious and striking discrepancies between the accounts given by different authors concerning the nature and order of succession of the strata which in Messrs. Meux's well were found between the Gault and the Devonian. This has apparently arisen from the circumstance that the strata in question consisted of hard and compact oolitic limestones alternating with marls of a more or less sandy character. Owing to the method of working with the diamond rock-drill the cores brought up consisted almost entirely of the former kind of rock, the softer marls being broken up and to a great extent washed away in the process of boring. As specimens of the oolitic limestone were found at short intervals, it was not unnaturally supposed by those who did not watch the boring and measure the cores brought up, that the boring was carried on wholly in that rock." . . .

"The fossils contained in the oolitic limestones . . . were nearly all in the condition of casts and most of them difficult of determination." . . .

"On washing the softer beds . . . I found such a large number of the minute forms so closely in agreement with those occurring at Richmond, though in a less perfect state of preservation, that no doubt remained, in my mind, as to the Great-Oolite age of the rocks." . . .

"It has sometimes been said that the upper portion of the 64 ft. of rock . . . was of a sandy nature; but this is certainly a mistake. From the very top of the series . . . Mr. C. Moore received a specimen of limestone, which on microscopical examination is seen to be perfectly oolitic in character" as also was the case with other specimens from lower depths.

"It thus becomes evident that the whole thickness of 64 ft. . . consisted of oolitic limestones with bands of marl between them, exactly answering in fact to much of the Great Oolite in other parts of this country. Of truly arenaceous strata, I have been able to find no evidence whatever, and there is but a slight admixture of sandy material in some of the marls." In one specimen however "from a depth of 1,008 ft. the insoluble matter amounted to 35 per cent."

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\* *Quart. Journ. Geol. Soc.*, vol. xxxiv. pp. 908, 915, 916.

After examining the specimens at the Jermyn Street Museum, PROF. JUDD concluded that "the identification of Neocomian fossils in the rock from Meux's Brewery completely breaks down upon re-examination, and as we have already seen there is abundant evidence of its Great-Oolite age."\*

At Richmond the Lower Jurassic beds are present in greater thickness, reaching 87½ feet, and details of them are given under Well-sections. For the following general account we are also indebted to Prof. Judd's paper,† the whole being described as "a series of oolitic limestones alternating with clayey and sandy beds."

"At first sight the upper beds of this series do not appear to differ in a very marked manner from those lying upon them, except in the absence of grains of sand and glauconite. But this probably arises from the fact that the upper series of beds is made up of rocks reconstructed for the most part of materials derived from the strata on which they rest."

"It may be remarked that all the beds, as is so commonly the case with Jurassic limestones which have not been exposed to weathering action, are of a more or less marked deep blue colour. This colour is due to the presence of iron-pyrites, which was proved by chemical analysis in the case of one sample of these rocks to be present in it to the extent of 2·4 per cent."

"In these limestones well-preserved fossils are very rare. The comminuted shell fragments of which so many of them are largely made up, are for the most part quite unrecognizable."

On reaching however the bed of blue clay with limestone bands, at a depth of about 1,204 feet, "an enormous number of fossils occurred; Brachiopoda, Bryozoa, Echinodermata, and many other forms being found in the richest profusion, and it soon became apparent that the forms of life represented in these beds were for the most part identical with those occurring in the Bradford Clay of Wiltshire, . . . that is to say, that they were of Great-Oolite age."

"It cannot be doubted that the colonies of branching Bryozoa and Crinoids, with the Brachiopoda in every stage of growth lying among them, were overwhelmed and buried by a sudden influx of muddy sediment over the sea-bottom where they grew. So exquisitely are many of these fossils preserved, that . . . they serve in not a few cases to clear up difficulties which had hitherto existed concerning the structure of the species to which they belong."

From the absence of these beds in any of the borings north of that at Meux's PROF. JUDD remarks "that whatever may have been the former extent of these Lower-Oolite strata, they are now confined to the southern part of the metropolitan area, and abut against the southern flank of the great Palæozoic axis."

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\* *Quart. Journ. Geol. Soc.*, vol. xl. pp. 744-747.

† *Ibid.*, pp. 741-743, 747-749.

"Although . . . there is a general correspondence in the . . . Great-Oolite strata in the two localities . . . yet, when critically examined, some very interesting and suggestive differences become apparent."

"Under Richmond the strata consist of compact limestones, with a very thin interstratification of clay, the only sandy beds being found towards the base . . . The fossils . . . are not only all truly marine but are for the most part such as would inhabit moderately deep water. Nor do the fossils, as a rule, appear to be rolled and waterworn, as is the case with those found in littoral deposits, but they are quite fresh and unbroken." . . .

"Very different is the state of things found under the Tottenham Court Road. There the specimens are all much broken and waterworn, many of them being coated with a thick layer of calcic carbonate. It is evident that the beds containing these fossils were accumulated in much shallower water than those at Richmond. Among the fossils found at Meux's well Mr. C. Moore detected some which he suspected to be terrestrial, freshwater, and brackish-water forms . . . This and the dwarfed condition of many of the Gasteropoda and other shells led Mr. C. Moore to the conclusion that while all the strata were of shallow-water origin, some of them were probably deposited in brackish water, while a number of the fossils might have been washed down by rivers."

Of the pieces of coal, at Meux's, PROF. JUDD says "These fragments appear to me to be very similar to the imperfect Jurassic coals of Brora and the Western Isles of Scotland. The engineer . . . informed me that at some periods during the boring in the Oolitic strata, the water forced down the well came up "as black as ink." It is not impossible, therefore, that actual Jurassic coal seams were passed through." . . .

"From a careful comparison of all the facts of the case, it is clear, that while the Great-Oolite beds under the Tottenham Court Road were deposited in comparatively shallow water, and in close proximity to the land, the beds of the same age under Richmond were laid down in much deeper water. Hence we may fairly infer that during the Great-Oolite period the northern half of the Palæozoic ridge under London formed dry land, while the southern half was submerged beneath the waters of the ocean, and became gradually buried under its sediments."

We are not here concerned with the Oxford Clay, which has been found beneath Lower Greensand at Chatham, just beyond our district: it is enough to note that no deposit of Middle Jurassic age has yet been found in our area, whilst the Upper Jurassic period is unrepresented in any of the deep borings of the London Basin, unless the clay touched at the bottom of the Holkham well, in North Norfolk, should prove to be Kimeridge Clay. In the boring of the Subwealden Exploration, far to the south, this clay was found in great thickness.

The following list of fossils, from the two borings above alluded to, has been compiled from pp. 743, 745 and 747 of Prof. Judd's paper, with some corrections in synonymy by MR. G. SHARMAN.

Great Oolite Fossils.	London.	Richmond.
<i>Lamna</i> , teeth - - - - -	—	x
<b>GASTEROPODA.</b>		
<i>Cerithium</i> , sp. - - - - -	x	
<i>Chemnitzia</i> , sp. - - - - -	x	
<i>Cylindrites excavatus</i> ? <i>Lyc.</i> and <i>Mor.</i> - - - - -	x	
<i>Natica cincta</i> , <i>Phil.</i> (?) - - - - -	x	
„ sp. - - - - -	—	x
<i>Nerinea Eudesii</i> , <i>Lyc.</i> and <i>Mor.</i> - - - - -	—	x
„ <i>punctata</i> (?), <i>Voltz.</i> - - - - -	x	
<b>LAMELLIBRANCHIATA.</b>		
<i>Avicula</i> , sp. - - - - -	—	x
<i>Gervillia</i> or <i>Pteroperna</i> (?) - - - - -	x	
<i>Lima duplicata</i> , <i>Sby.</i> - - - - -	x	
„ sp. - - - - -	—	x
<i>Nucula</i> , sp. - - - - -	x	
<i>Ostrea gregaria</i> , <i>Sby.</i> (? young of <i>O. Marshii</i> , <i>Sby.</i> ) - - - - -	x	x
„ <i>Sowerbyi</i> , <i>Lyc.</i> and <i>Mor.</i> - - - - -	x (young)	x
„ <i>subrugulosa</i> , <i>Lyc.</i> and <i>Mor.</i> - - - - -	x (young)	x
<i>Pecten articulatus</i> (?) <i>Schlot.</i> - - - - -	x	
„ <i>rushdenensis</i> , <i>Lyc.</i> - - - - -	—	x
<i>Pholadomya Heraulti</i> , <i>Ag.</i> - - - - -	—	x
<i>Pinna</i> , sp. - - - - -	x	x
<i>Tancredia axiniformis</i> , <i>Phil.</i> - - - - -	x	
<i>Trichites</i> , sp. - - - - -	x	x
<i>Trigonia costata</i> , var. <i>pullus</i> , <i>Sby.</i> - - - - -	x	
„ <i>Moretoni</i> ? <i>Lyc.</i> and <i>Mor.</i> - - - - -	x	
<b>BRACHIOPODA.</b>		
<i>Rhynchonella concinna</i> , <i>Sby.</i> - - - - -	x (young)	x
<i>Terebratula digona</i> , <i>Sby.</i> - - - - -	x (young)	
„ <i>maxillata</i> , <i>Sby.</i> - - - - -	x (young)	x
„ ( <i>Dictyothyris</i> ) <i>coarctata</i> , <i>Park.</i> - - - - -	—	x
<i>Thecidium triangulare</i> , <i>D'Orb.</i> - - - - -	x	
<i>Zellania globata</i> , <i>Sby.</i> - - - - -	x	
<b>POLYZOA.</b>		
<i>Diastopora diluviana</i> , <i>Lamx.</i> - - - - -	x	x
„ <i>Lamoureuxii</i> , <i>Haime</i> - - - - -	—	x
„ <i>microstoma</i> , <i>Mich.</i> - - - - -	x	x
„ „ var. <i>connectens</i> , <i>Vine</i> - - - - -	—	x
<i>Entalophora richmondensis</i> , <i>Vine</i> - - - - -	? x	x
„ „ var. <i>pustulopora</i> , <i>Vine</i> - - - - -	—	x
„ <i>straminea</i> , <i>Phil.</i> - - - - -	—	x
<i>Fasciculipora Waltoni</i> , <i>Haime</i> (?) - - - - -	x	x
<i>Heteropora conifera</i> , <i>Lamx.</i> - - - - -	—	x
<i>Idmonea triquetra</i> , <i>Lamx.</i> - - - - -	x	x
<i>Lichenopora Phillipsii</i> , <i>Haime</i> (?) - - - - -	x	x
<i>Stomatopora dichotoma</i> , <i>Lamx.</i> - - - - -	x	x
„ <i>Waltoni</i> , <i>Haime</i> - - - - -	—	x
<i>Terebellaria increscens</i> , <i>Vine</i> - - - - -	x	x
<b>ANNELIDA.</b>		
<i>Serpula intestinalis</i> , <i>Phil.</i> - - - - -	—	x
„ <i>lacerata</i> , <i>Phil.</i> (given as <i>S. lacinatus</i> ) - - - - -	—	x
<i>Vermicularia nodus</i> , <i>Phil.</i> - - - - -	—	x

Great Oolite Fossils.					London.	Richmond.
ECHINODERMATA.						
Acrosalenia pustulata, <i>Forbes</i> (spines)	-	-	-	-	—	x
" (spines)	-	-	-	-	x	x
Apiocrinus, sp.	-	-	-	-	x	x
Astropecten (marginal and eye plates)	-	-	-	-	x	x
Bourgueticrinus, sp. ? or Thiollhierierinus	-	-	-	-	—	x
Cidaris bradfordensis, <i>Wright</i> (spines, and plates)	-	-	-	-	x	x
Cidaris, sp.	-	-	-	-	x	x
Hemicidaris (spines)	-	-	-	-	—	x
Pentacrinus scalaris, <i>Goldf.</i>	-	-	-	-	x	x
Pentacrinus, sp.	-	-	-	-	x	x
<hr/>						
Entomostraca (12 species)	-	-	-	-	—	x
Foraminifera (16 species)	-	-	-	-	—	x
Sponges (5 species)	-	-	-	-	—	x

### Lower Greensand.

Strange to say there is no certain record of the presence of this formation in our district! though it must certainly underlie the Gault, in part at least, of the north-western corner of Sheet 7, near Risborough.

The 18 inches of "Carstone" which MR. ETHERIDGE records as occurring at Ware, is probably merely the ferruginous base of the Gault, rather than a representative of the Lower Greensand.

MR. GODWIN-AUSTEN was of opinion that the Lower Greensand has thinned away "all along the line of the Thames Valley.\*

From the fact that water was found after piercing 172 feet of Gault, with phosphatic nodules at the base, in the Loughton boring (see Well-sections) it may be inferred that the Lower Greensand occurs here, at a depth of about 1,100 feet; but of course any other permeable deposit might yield the water.

At the south-eastern corner of our district it is possible that the Lower Greensand has only a slight underground range; for at Chatham, just beyond our border, it was found to be only 14 feet thick.

The beds at a depth of about 1,140 to 1,150 feet at Richmond which have been classed as probably Neocomian, may be of this age, though differing from anything seen in the outcrop to the south. Their details are given in the Well-sections, and the following account is taken from that great fount of information, the paper by PROF. JUDD, which has been so much quoted already.†

"The Gault was found to rest directly upon beds of limestone of a somewhat peculiar character. The uppermost portion . . . very closely resembles, both macroscopically and microscopically, certain varieties of Kentish Rag."

\* Report of the Coal Commission, vol. ii. p. 433. (1872.)

† *Quart. Journ. Geol. Soc.*, vol. xl. pp. 738-740.

"The insoluble residue of this rock, which varied in amount from 3 to 13 per cent. . . was found to consist of glauconite grains more or less decomposed, fine particles of sand, and some clayey matter. In this respect it also resembled Kentish Rag."

"But as we proceed downwards, these limestones appear to gradually alter in their character and pass into a rock of a totally different appearance, when viewed in thin sections under the microscope. The lower beds . . . consist of a fine-grained calcareous paste, through which are scattered in greater or less abundance oolitic grains, fragments of bivalves, small uni-valves, and Foraminifera coated with a film of calcic carbonate, the whole being impregnated with finely divided iron-pyrites." A clay band in this limestone was found, by washing, to contain "an immense number of detached oolitic grains, a number of waterworn shells, Bryozoa, Foraminifera, and fragments of Echinoderms, often coated with . . . calcic carbonate. In lesser numbers are found grains of glauconite, particles of iron-pyrites . . . fragments of teeth, and spines of fish . . . many particles of imperfect coaly material, and a few of anthracite, also some waterworn fragments of sandstone and other hard rocks." These substances seem to have been derived for the most part from the underlying Jurassic limestone. "A few specimens of Foraminifera and Ostracoda appear to have belonged to the period of the deposition of these rocks, and not to have been derived from any older formation;" of these however PROF. T. R. JONES says "that there is nothing particularly characteristic of any formation, similar forms ranging through Secondary, Tertiary, and Recent times."

The bed at the base "is of very peculiar character . . . scattered through this clay are many subangular and rounded fragments, some of them of considerable size, of a micaceous sandstone, strikingly like that of the Coal-measures, of quartzite and indurated sandstone, of subcrystalline limestone, and of other hard rocks," besides "a number of phosphatic nodules."

"That the matrix of this remarkable 'junction-bed' was derived from the denudation of the underlying Great Oolite deposits, there cannot be the smallest doubt. Waterworn fragments of the oolitic limestone, oolitic grains disengaged from their matrix, . . . with Jurassic forms of Brachiopoda and Bryozoa, abound in it. Fragmentary and waterworn teeth of . . . Jurassic genera of fish . . . also occur in it in great numbers."

"The foreign rock-fragments in the mass appear to have been certainly derived from Palæozoic deposits, which must have been *in situ* at no great distance."

"The presence of phosphatic nodules probably indicates . . . a considerable interval of time, during which sedimentation was suspended."

"The limestones contain a few oysters, having the appearance of being dwarfed from the unfavourable conditions of brackish water."

"Although it must be confessed that the 10 ft. of strata underlying the Gault at Richmond may be of any age between that of the Great Oolite and that of the Gault, yet . . . they may be most probably referred to some part of the Neocomian period."

"In their nature and relations, though not in their age, these beds present some analogies with the "Tourtia," which in Belgium is so frequently found separating the rocks of the Palæozoic ridge from the overlying Upper Cretaceous strata."

#### GENERAL CONCLUSIONS.

In the first place it will be well to get our main facts collected together, in such a way as to bring them before the eye at once suppressing details that have no bearing on the general issue. For this purpose, as in the historical review of the subject, we must go beyond our district and refer to all the deep borings in the London Basin that have gone through the Chalk. These number 26, at 24 places, and are nearly equally divided between the tracts to the north and those to the south of the Thames.

The details of these sections are in print, except in the case of East Horsley, which is reserved for the Geological Survey Memoir on the district. Those of the Streatham well are printed for the first time in this work, in which too additional particulars of the Bushey and Cheshunt wells are given.

The information thus yielded is summarised in the accompanying tables, in which there are references to the publications where details of those borings that are beyond our district, are to be found. The others will be described in the Appendix on Well-sections in this Memoir.

Secondly it is advisable to get rid of a possible source of misunderstanding. Geologists have unfortunately been in the habit, to which I own to having given way, of speaking of the underground *ridge* of older rocks. As a matter of fact there is nothing whatever in the nature of a ridge, *plain* would be a far more correct term. As far as we know, the inequalities of the Pre-Cretaceous surface under the London Basin seem to be less than those of the present surface, showing nothing to approach the sharp slopes of the Chalk. Whatever features of hill-range, or of mountain, the older rocks may once have showed, they now present only those of a planed down surface.

For present purposes it is not the actual depth to the older rocks at any spot that is of most importance; but rather the depth below some fixed datum, that is to say as measured from the same level in all cases; for it is clear that the actual depth depends somewhat on the heights of the surface. It may be useful therefore to tabulate the depths from Ordnance Datum, or mean sea-level, to the older rocks, including therein the red beds (whether they may be Triassic or not), but not those of Jurassic age. As however there must be a considerable gap between the Cretaceous



ABSTRACT ACCOUNT OF DEEP BORINGS, through the CHALK, in the LONDON BASIN, SOUTH of the THAMES.  
SURREY and KENT.

GEOLOGICAL FORMATIONS PASSED THROUGH, ETC.	East Hoveley. The Towers (outside the district).	Blohmund. Waterworks.	Streatham. Southwark and Vauxhall Water-works.	Caterham. Waterworks (outside the district).	Crosness, near Brith. Southern Outfall.		Shoreham (outside the district).	Frindsbury. Chatterden Barracks (outside the district).	Frindsbury. Whitewall Cement Works (outside the district).	Strood. Stewart and Spence's Oil Mills (outside the district).	Chatham Dockyard Extension (outside the district).		Chatham Asylum (outside the district).	Dover. Convict Prison (outside the district).	St. Margaret's. Trial-boring, on the shore (outside the district).	Formations, etc.
	About 300	17	110	About 707	No. 1. No. 2.	No. 1. No. 2.	—	127	30 above H.W.M.	15†	54 above H.W.M.	18	254 above the Stour.	280	Little above sea.	
1. Made ground, Alluvium, and Drift	13†	10	10	—	35? 39	13	—	—	—	48	254 or 174	7 (of 12 3.)	—	1	9	1
2. London Clay	—	160	163†	—	—	—	—	101	—	—	3 or 24	—	—	—	—	2
3. Lower London Tertiaries	20†	854	784†	89	111? 646	—	—	1884	—	—	6844 or 689	—	—	—	—	3
4. Chalk	817†	671	683	369?	688? 12	200	—	680 or 683	618	505	—	683	733	674	539	4
5. Upper Greensand	—	16	29?	53?	—	10	—	193 or 190	—	—	—	—	—	—	—	5
6. Gault	6	201†	188	343?	148	226	—	3	192	185	183†	138	5	143	19	6
7. Lower Greensand	—	10?	—	20	—	26+	—	—	5	15	touched	41	—	31	—	7
8. Walsden	—	—	38†	—	—	—	—	—	—	—	—	—	—	83	—	8
9. Jurassic	—	87†	138	—	—	—	—	—	—	—	—	—	—	—	—	9
10. Marl, sandstone, clay etc.	—	207	—	—	53	—	—	—	—	—	—	—	—	—	—	10
Total Depth	874	1,446 about	1,253	874	980	475	1,165	815	757	903†	965	740	931	567		

ABSTRACT ACCOUNT OF DEEP BORINGS, THROUGH THE CHALK, IN THE LONDON BASIN, NORTH OF THE THAMES.  
ESSEX, HERTS, MIDDLESEX, NORFOLK, AND SUFFOLK.

UNDERGROUND OLDER ROCKS.

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GEOLOGICAL FORMATIONS PASSED THROUGH, ETC.	Bushey. Colne Valley Waterworks.	Kentish Town.	Tottenham Court Road. Meux's.	Millie End. Mann and Co.'s.	Chestnutt. Turnford. New River Co.	Ware. New River Co. (outside the district).	Loughdon. Great Eastern Railway.	Saffron Walden (outside the district).	Holkham, near Wells. Norfolk (outside the district).	Coombe, near Stowmarket. Suffolk (outside the district).	Harwich (outside the district).	Norwich. Cartow Works. Colman's (outside the district).	Formations, etc.
Height, above Ordnance Datum, unless otherwise stated.	174 above H.W.M.	About 84.									6 (above H.W.M.)		
1. Made ground, Alluvium, and Drift	5	236	33?	304	1024	14	167	10	20	57	25	13	1
2. London Clay	—	894	64	844	—	—	76	—	—	—	53?	—	2
3. Lower London Tertiaries	—	645	724	96	6814	544	651?	—	—	817?	80?	1,146	3
4. Chalk	686		6554	654					635		890		4
5. Upper Greensand	—	134	23	20	40? (pieces)	77?	30?	(4, 6, 7, and 9?)	Red Chalk. 8	10	?	?	5
6. Gault	9	1304	160	—	1564? (7 more)	160	172	1,003 or	10	11	61	38?	6
7. Lower Greensand	—	—	—	—	—	14	touched?	—	70	—	—	—	7
8. Jurassic	—	—	—	—	—	—	—	—	—	—	—	—	8
9. Clay, sandstones, etc., chiefly red (Trias?)	—	1884	64	—	—	—	—	—	—	—	60	—	9
10. Carboniferous. Dark slaty rock	—	—	—	—	—	—	—	—	—	—	—	—	10
11. Devonian	—	—	80	—	204	—	—	—	—	—	—	—	11
12. Upper Silurian (Wenlock Shale)	—	—	—	—	—	25	—	—	—	—	—	—	12
13. Total Depth	700	1,303	1,146?	875	1,010	8814	1,006?	1,004 or 1,013	745	895	1,008	1,196	13

Series and such Jurassic beds as have been found, it may be well to add a column for the base of former.

Place.	Depth in Feet below Ordnance Datum.	
	To Base of Cretaceous.	To older Rocks.
Richmond - - - -	1,185	1,222
Streatham - - - -	1,010	1,048½
Crossness - - - -	1,008	1,008
Meux's - - - -	917	981
Kentish Town - - -	abt. 980	abt. 980
Cheshunt - - - -	abt. 880	abt. 880
Ware - - - -	abt. 710	abt. 710
Chatham - - - -	925	—
Harwich - - - -	abt. 1,015	abt. 1,015

The last three places are beyond our district; but Ware has been placed with those above because it continues the line northward from London. Disregarding therefore the last two, and confining our attention to the others, which range from the Valley of the Thames northward, it will be seen that there is a steady decrease in the depth to the floor of older rocks as we go northwards, there being however little difference between Crossness and Meux's as far as north and south are concerned.

That this rise of the surface of the older rocks continues far beyond Ware is most unlikely, for in that case those rocks should soon come to the surface, whereas northward we find the Cretaceous beds duly underlain by Jurassic beds of great thickness and of broad outcrop, and these in turn by the Trias. We may infer therefore that from near Ware the older rocks soon sink slowly northward.

The northerly rise of the old surface from near London is moreover accompanied by a northerly rise of the beds. It is only on the south that we find the Jurassic Series represented, and also the Red Beds, of whatever age they may be; but Devonian rocks soon set in, at first not far below the Gault and then directly beneath this last; whilst on the north only has a Silurian formation been found.

Further east too the like seems to occur, as far as the more scanty and wider-spread information tells us. In the Sub-Wealden Boring Jurassic beds are almost abnormally thick; the higher of them have disappeared at Chatham, where Oxford Clay underlies the Lower Greensand; and at Harwich Lower Carboniferous rock underlies the Gault.

From our present knowledge therefore we have a right to infer *generally* that whilst older beds rise up in succession northward from the neighbourhood of London, southward, on the other hand, the Jurassic beds are likely to thicken, and therefore that the surface of the older rocks will sink in that direction.

To extend such general inference however to the statement that, because Devonian rocks occur at London and at Cheshunt,

whilst Silurian rock is found at Ware, therefore no beds of newer age will be found northward of London, seems to me unwarrantable, for reasons that have been already given in part (pp. 21-23). Such a proceeding is arguing back from the general to the particular, which is not always safe. Especially is this the case in drawing negative conclusions.

The danger indeed of negative conclusions is well illustrated by the very subject under discussion. The first man to work out the subject of the underground extension of older rocks under the London Basin, the great geologist GODWIN-AUSTEN, came to the conclusion that "there is no part of the Oolitic series beneath London";\* but these have already been found at three places, London, Richmond, and Streatham, in the Valley of the Thames, as well as at Chatham, but just outside it and in a tributary-valley.

On the other hand one must also deprecate the too definite drawing of general conclusions from scattered data.

The London Basin is a tract of large extent, even when the name is used in the restricted sense of the Tertiary district, and still more so therefore in the wider sense which takes in the bordering Chalk, with its Tertiary outliers (the sense in which I use the name). Now in all this great area there are only 9 borings that are known to reach Jurassic or older rocks, or 10 if Saffron Walden be included. Of these, 7 reach to the older rocks, or, omitting the red beds, which are of doubtful age, only 4. Is this evidence enough for concluding that Coal Measures, or any other formations, do not occur under the London Basin?

Moreover, turning to our own special district, in which most of these borings occur (and including Ware, which is a little beyond), we find that the nearest two that have reached rocks of Pre-Jurassic age (Meux's and Kentish Town) are 3 miles apart, that the next nearest pairs (Cheshunt and Ware, Meux's and Streatham) are  $6\frac{1}{2}$  miles apart, that Richmond and Streatham are 8, and that Richmond and Meux's are 9 miles from each other, Crossness being 11 miles from any. Surely this is hardly enough to justify one in saying what must happen in the spaces between.

It has been assumed, from the probable general strike of the older rocks being eastward and westward, and from the occurrence of the oldest rocks to the north, that the recorded dips, of  $30^\circ$  and upwards, are to the south; but this conclusion is really only a probability of no great strength. These old rocks are subject to folding and contortion to such an extent that it is dangerous to assume in what direction they may dip at any spot. Moreover, disturbances oblique to the direction of the main axis are almost sure to occur, and it would be wonderful if large faults were wholly absent.

Again the few borings that have as yet been carried into Pre-Cretaceous beds have proved the presence, in what before was unknown ground, of the following great Pre-Cretaceous groups:—Middle Jurassic, Lower Jurassic (three cases), Lower Carboniferous, Upper Devonian (two cases), and Upper Silurian. In

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\* Report of the Coal Commission, vol. ii. p. 432.

other words 9 borings have added 5 formations to our list, besides the doubtful red rocks, which have been found in 4 cases. Does it not look likely that further trials will add fresh formations? And as Lower Carboniferous rock has already been found is it probable that all the rest of the great Carboniferous Series has either been swept away, or was never deposited over so large a tract?

Any argument based on the thinning of the Coal Measures southward, from the North of England, or on the possible decrease in the amount of coal beds therein (and it should be remembered that coal is a comparatively small constituent of the Coal Measures) seems to me to have been already met by PROF. PRESTWICH. One of our greatest coal-fields is in the south, that namely of South Wales. Eastward of this, and continuing along the line of the great disturbance that has resulted in bringing the older rocks within touch under London, is the Bristol coal-field. Much farther east again, and still along the same line, are the coal-fields of Belgium and of the North of France.

What evidence we have therefore seems to lead to two conclusions: that Coal Measures are likely to occur somewhere along the line of the Thames Valley, or in neighbouring tracts; and that those Coal Measures are likely to yield workable coal.

It is rash to attempt to foretell the future; but it seems to me that *the day will come when coal will be worked in the South East of England.*

It may be well to notice here some possible evidence of the presence, beneath the Cretaceous beds, either in some eastern part of the London Basin, or further eastward, of rocks other than those that have yet been recorded; though that evidence can only be brought forward doubtfully or suggestively.

The layer of phosphatic nodules that has been worked, along the base of the Chalk, in Cambridgeshire and Bedfordshire, has also yielded a number of stones and small boulders. These were first noticed by PROF. H. G. SEELEY,\* who noted the occurrence of granites, sandstones, hornstones, quartzites, metamorphic rocks, and traps, and suggested that they may have come from regions of Palæozoic and of Plutonic rocks in France.

PROF. SOLLAS and MR. JUKES-BROWNE drew attention to these fragments in some detail,† giving a description of 12 specimens, the largest 14 × 12 × 6 inches in size. They inferred that the stones might have come from Scotland and from thence eastward to Norway.

PROF. BONNEY, in a paper which was read before that last noticed, though printed a little after it,‡ also noticed these stones,

\* *Geol. Mag.*, vol. iii. pp. 303, 304. (1866.)

† *Quart. Journ. Geol. Soc.*, vol. xxix. pp. 11-16. (1873.)

‡ *Proc. Geol. Assoc.*, vol. iii., no. 1, pp. 7, 8, 19. (1873.)

and looked conjecturally to the north-east for their origin, adding that "none of the erratic blocks are sufficiently characteristic to allow us to identify their localities."

Two years later the same author recurred to the subject, and expressed the opinion "that many of the rocks can be identified with the palæozoic 'grauwackes' of the southern and eastern parts of Scotland, and others appear to resemble closely Scandinavian rocks."\*

The last reference to these erratics comes from MR. JUKES-BROWNE, who alludes to the kinds of rock found, noting fresh finds.†

At the present time the large collection of transported stones from the Cambridge nodule-bed, belonging to the Woodwardian Museum, is at Jermyn Street, where it was sent, on the suggestion of MR. JUKES-BROWNE. It has been examined by various geologists, amongst others by the Director General of the Geological Survey, DR. A. GEIKIE, and the general opinion seems to be that it is a very difficult matter to trace back the stones to their birth-place: thus DR. GEIKIE has seen none that he would like to certify to as of Scotch origin.

I have myself carefully examined the larger specimens, over 30 in number, with the following result:—

*Sandstones* form more than a half, and these are of various sorts. There is a specimen which seems to have once been calcareous, but from which the calcareous matter has been dissolved out, and one would take it to be of Secondary age. Two specimens are suggestive of Lincolnshire Neocomian, one being of a greenish tint and with glauconite grains. Some are stained of a reddish-purple, and are micaceous, being much like stained Carboniferous sandstone, and sometimes not unlike specimens from the Richmond boring. Others again are grey, of finer grain, more compact, and sometimes finely bedded, having a likeness to some still older rocks.

Of *Limestone* there is but one specimen, and that is very dark grey, and like beds of Carboniferous age.

There are also various gneissic, quartzitic, and slaty rocks, clearly of great geological age, and some stones of igneous origin.

In looking through the smaller specimens I noticed a piece of silicified wood, that one would take to be of Secondary age, and a hard banded slate, that may be Cambrian.

Before seeing these specimens, in thinking over what had been told me as to the difficulty of making out their places of origin, it occurred to me that possibly such a collection of rocks might have been derived from places where the parent rocks cannot now be seen, owing to their being hidden under an accumulation of later deposits. Being then in the midst of work at the under-

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\* Cambridgeshire Geology, pp. 33, 34. 8°. Cambridge and London. 1875.

† Memoirs of the Geological Survey. England and Wales. The Geology of the Neighbourhood of Cambridge, pp. 25, 26. (1881.)

ground range of old rocks under the London Basin it naturally occurred to me that the district under my consideration might perhaps help to a solution of the problem, as being one in which we know but little of the character of the old rocks underground.

The difficulty at once arose of where we could find a tract where the Chalk ocean might have been in contact with these old rocks. All our borings prove the interposition of a mass of Gault between the Chalk and the old rocks: some also of Upper Greensand. This last formation though need be a source of no anxiety, as it thins out along the eastern part of the great Chalk tract, both on the north and on the south.

The Gault too just disappears at the far north-east (at Hunstanton), unless partly represented by the thin Red Chalk; but there we have a fair thickness of Lower Greensand and probably a great thickness of Jurassic clays etc. separating us from older rocks.

Turning southward however we find that our most easterly boring that has passed through the Gault to the old rocks, at Harwich, shows a great thinning in the former, which is but 61 feet thick (including perhaps some Upper Greensand). If this thinning continues eastward, we should get the required site, from which the Chalk might have derived some of the rocks in question.

Now, according to PROF. PRESTWICH,\* at and near Calais only 29 to 33 feet of Gault and Greensands, and at Flines Nord only 3 feet, separates the Chalk from Carboniferous or older rocks (and it may be a question whether the basal bed of the Chalk is not here taken as Upper Greensand); whilst at other places there is absolute contact.

Reasoning therefore from the thinning of our Gault eastward, and from the thinning of the underlying Cretaceous and Jurassic beds towards the hollow of the London Basin, one may fairly infer that near our eastern coasts (in Essex, Suffolk and part of Norfolk) and thence eastward towards France and Belgium, there is likely to be a tract where the Chalk rests at once on much older rocks, from which may have been derived some of the boulders or stones that are found in the Cambridge nodule-bed, and also, a few feet higher, in the Chalk Marl of Gayton, near Lynn.

On that supposition we may speculate on further additions to our list of underground rocks from fresh borings, and, though lumps of coal are not amongst the stones from the base of the Chalk, we have no reason to shut out the Coal Measures from possible additions, for the specimens are of hard rocks, such as could stand the wear and tear of distant transport, and some of them are like Coal Measure sandstone.

The suggestion above-made as to the possible source of the erratics of the Cambridge nodule-bed is similar to that made by

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\* *Pop. Sci. Rev.*, vol. xi. p. 231. (1872.)

PROF. SEELEY (see p. 46); but it was arrived at quite independently, and for different reasons. PROF. SEELEY thinks that the nodule-bed is of Upper Greensand age, and regards the stones as "the only representatives of the siliceous part of the Greensand . . . fragments of the parent rocks whence the mass of the Greensand of thicker sections came." Later observers take the bed as merely the base of the Chalk, in much the same position as the so-called Chloritic Marl of the Isle of Wight, which overlies the Upper Greensand. PROF. SEELEY moreover looks to the south and to the south-west, instead of to the south-east, for the source of the material, which is a very different thing.

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It is sometimes said that the geology of England has been worked out, and that there is nothing left for future observers but the settlement of details. This may be true in a very great measure; though I venture to say that the mass of details waiting for the geologists of the future is vast, and in many cases of great importance. But more, whilst we know so little of what lies hidden deep underground in the South East of England, we may fairly assert that one of the greatest problems in English geology remains unsolved.

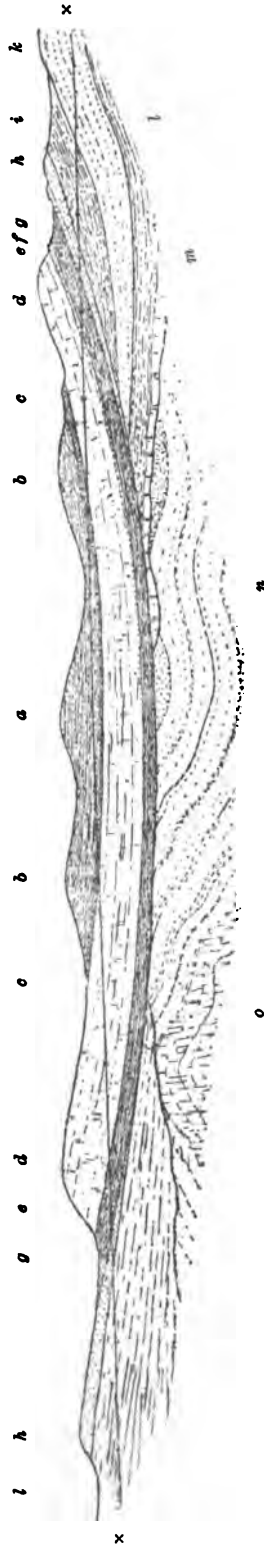
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The section, fig. 1, will perhaps make the underground range of old rocks more clearly understood. Of course detailed accuracy is out of the question in this small diagram; but I have tried to show as much of the geological structure of the Tertiary and Cretaceous rocks in and near London as possible in the space: for instance, the general sharper dip on the south; the thinning of the Lower London Tertiaries to the north; the slight irregularity of the thickness of the Chalk; the general absence of the Upper Greensand on the north, in Bedfordshire, &c. (it occurs westward however); the greater thickness of the Gault at the outcrops, especially on the south, and of the Lower Greensand on the south; &c. It should be distinctly understood that the representation of the old rocks is purely ideal, and is merely meant to show the general nature of their occurrence.

This figure is based on the one above alluded to (p. 14); but it has been drawn afresh, by MR. J. G. GOODCHILD.



Figure 1. Generalized Section across the London Basin, from North to South, showing the Underground Range of Older Rocks.



x Sea-level.

- a Bagshot Sand (of Hampstead).
- b London Clay.
- c Lower London Tertaries.
  - { Oldhaven and Blackheath Beds, on the south only.
  - { Woolwich and Reading Beds.
  - { Thanet Sand, on the south only.

- d Upper Chalk.
- e Middle and Lower Chalk.
- f Upper Greensand.
- g Gault.
- h Lower Greensand.
- i Weald Clay.
- k Hastings Beds.

- l Upper and Middle Jurassic Beds, clays on the north.
- m Lower Jurassic limestone, with clay, in the centre.
- n Red Rocks; and Devonian (possibly with Carboniferous in places).
- o Silurian.

Vertical scale exaggerated.

## CHAPTER 4. CRETACEOUS BEDS (BELOW THE CHALK).

MR. JUKES-BROWNE, who is working on the Cretaceous beds, has taken charge of the part of this Memoir that refers to them. In his account the descriptions already published, either in the Memoir on Sheet 7 or in the larger one on the London Basin, are worked in, with some additional matter from my own notes; but the greater part of chapters 4, 5, and 6 is from his own observations, in subdividing the Chalk and in the general revision of Cretaceous work. We have gone through the whole together.

### GAULT AND UPPER GREENSAND.

#### *General Remarks.*

The beds ordinarily known as Gault and Upper Greensand are really stages of one group or formation, to which a new name should eventually be given. In the counties of Oxford and Bucks. this formation consists of the following divisions:—

Upper	{ Green sand (? Warminster Beds).
Greensand.	{ Siliceo-calcareous stone (Malmstone).
Gault.	{ Sandy and marly clays (Upper Gault).
	{ Stiff dark blue clays (Lower Gault).

Each of these divisions appears to pass gradually into the one above it, but, as the hard stone usually causes a decided feature or rise in the ground, a line has been drawn along this slope and is generally regarded as forming the base of the Upper Greensand.

In the area on the north (Sheet 46 S.W.) the Lower and the Upper Gault are separated by a seam of phosphatic nodules, and well-sections near Tring prove the thickness of these two divisions to be 150 and 80 feet respectively; there is reason to believe that this nodule-bed is continued through the district, in Sheet 7, but it was not seen during the re-survey of the ground.

The Gault has not been pierced by any boring near its outcrop, so that its full thickness there is not known; it seems probable however that the micaceous sandy marl which forms the upper-part of the Gault in the Tring district passes laterally into the calcareous stone or malm which is called Upper Greensand near Risborough, and if this be so the thickness of the clays which are coloured as Gault north of Risborough is probably less than that of the clays coloured as Gault near Tring.

#### *Gault.*

The lower beds are stiff dark bluish-grey clays; the uppermost beds, just below the malmstone, consist of hard grey sandy micaceous marl, which weathers into flaggy lumps, has a dark bluish-green tinge when wet, but dries to a pale grey.

No sections of these clays occur in the district except such as are afforded by ditches and stream-courses.

The upper marl can be seen in the watercourse by Bledlow Mill, at Pitch Green north of Bledlow, where it contains *Avicula gryphæoides*, and at the western end of the railway-cutting three quarters of a mile N.W. of Risborough Station. Marly clay of a slightly lower horizon is exposed in the watercourse below Longwick Mill. The hard sandy marl was found again by the mill on the brook about half a mile N.E. of Little Kimble church; some of it is very sandy and micaceous, coming out in flaggy lumps or blocks which are greenish-grey inside, and look like Chalk Marl when dry.

Coprolites have never been worked in this small area, but two distinct seams are known to occur in the district to the north (Sheet 46 S.W.); and I am informed by Mr. Harwood, of Clifton Hampden, that many years ago a seam of nodules, from 6 to 10 inches thick, was found on his father's farm at the northern end of Longwick, near Risborough, and was traced through a field on the adjoining farm. This layer is doubtless the higher of the two known to the north, and on the same horizon as the bed formerly worked at Puttenham and at Cheddington.

### *Malmstone.*

In the western part of its outcrop this division consists of a light-grey siliceo-calcareous rock which may be described as an impure earthy kind of "malmstone." It is a direct continuation of the stone which forms such a thick mass near Wallingford and Watlington (Sheet 13) and which has been described by DR. G. J. HINDE\* as similar in appearance and microscopic structure to the malmstone of Surrey and Hants. The harder beds are interbedded with courses of softer and more marly stone.

MR. W. HILL has been good enough to make a microscopical examination of specimens of malmstone from Risborough, and to report thereon as follows:—"The description of the malmstone of Wallingford, given by DR. HINDE, applies to these also. The rock is firm, and darker than that from the border of the Wealden Area. The matrix is very siliceous, the silica having probably been derived from sponge-spicules, which are common, but not abundant, in the specimens examined. The silica is in the amorphous, colloid, or crystalline condition described by Dr. Hinde, the minute globules being very abundant. There is but little calcareous matter, but Foraminifera are not uncommon."

To the north-east the stone-beds become thinner and more calcareous, the intervening marls becoming thicker and inseparable from those of the Upper Gault.

This division enters the sheet (7) near Henton and is first seen in the road-cutting west of the brook which forms the county-boundary between Oxford and Bucks.; here there are two thin beds of hard grey stone separated by about three feet of grey sandy marl, which is dark when wet, but pale when dry, and then looks like Chalk Marl: I found one specimen of *Ammonites auritus* here.

A better exposure was found in the cutting on the road over which the railway passes between Bledlow and Pitch Green. Three or four feet of the siliceo-calcareous malmstone are shown in the bank; 220 yards south of the bridge there is soft marl with stony beds containing *Avicula gryphæoides*.

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\* *Phil. Trans.*, 1885, p. 416.

The lower stone beds are well shown in the railway-cutting about three quarters of a mile north-west of Risborough Station, and the following notes were taken by Mr. Whitaker in 1864; "they consist of very light grey calcareous sandstone (often with a greenish tinge) and firm fissile sandy marl, showing a dip of  $2^{\circ}$  along the line south-eastward at the Risborough end of the cutting, which increases to  $7^{\circ}$  towards the middle, but a little further falls again to  $3^{\circ}$ ; the lowest part (at the north-western end) is more marly and not unlike Chalk Marl."

If the observed dips were continuous the thickness of the stone beds here would be considerable, but the dips probably indicate local undulations, and the real thickness of the beds between the Upper Gault marl and the soft green sand is probably not more than 40 feet.

The uppermost beds of this division are shown in the trench dug for the mill-tail at Park Mill; they consist of dark bluish-black micaceous sandy clay with harder layers containing calcareous matter; two of these are very hard, and lie about four feet apart, the softer beds between containing hard concretionary lumps of a similar material. In the hard beds *Ammonites awritus* (var.), *Avicula gryphæoides* and *Lima globosa* occurred.

The lower stone-beds were seen by Mr. Whitaker along the small stream running from Allscot to Longwick Mill, by Dr. FITTON "beneath the Lower Icknield Way at Chadwell Hill,"\* and by Mr. Whitaker just south of Kimblewick Farm, but none of these sections exposed any thickness of them.

The railway-cutting south of Kimble Station shows nearly the whole of this set of beds. North of the bridge over the line near Great Kimble there is at the top of the bank a little green sand passing down into a light-brown clayey sand, beneath this are beds of flaggy calcareous sandstone with layers of sandy marl, these beds rising at an angle of about  $2^{\circ}$ , so that some thickness of the sandstone is here exposed, probably 15 or 16 feet. The sandstone may also be seen along the course of the brook near the railway.

Fragments of hard calcareous sandstone, containing an *Ammonite* like *A. awritus*, but having a smooth rounded back, were turned out of a ditch on the northern side of the road by Little Kimble church, and similar fragments are strewn over the fields to the north-east; sandy marl with lumps of such stone is visible in the road-cutting west of Bushey Leys and a well at the new cottages at the top of the hill pierced 10 feet of soft sandy marl and 10 feet of hard grey marly stone below called by the workmen "ratchelly stuff."

Here, at the northern edge of the map, the stone beds are very different from those at the same horizon S.W. of Risborough, being much less siliceous and darker in colour, and occurring in thinner layers or lumps scattered through the micaceous sandy marl.

### Green Sand.

This is a soft dark green sand composed almost entirely of fine grains of quartz and of glauconite in the lower part, with a gradually increasing proportion of marly matter in the upper part; there seems indeed to be a complete passage from it into the Chalk Marl above, the bulk of the marly matrix gradually increasing and the number of glauconite grains becoming less. It is therefore in this district a difficult matter to say where the Greensand ends and the Chalk Marl begins. The total thickness of material containing glauconite is probably from 8 to 9 feet, but sometimes less.

This narrow band of greensand enters the map about half a mile S.S.W. of Henton; a dark green glauconitic marl is found in the watercourse below the Wainhill (or Winnall) springs and it appears to cap the ridge which runs northward toward Henton. Soft glauconitic marl of the same kind is exposed

\* *Trans. Geol. Soc.*, ser. 2, vol. iv. p. 271.

in the road-cutting close to the railway-bridge west of Bledlow, and again by the side of the road to Pitch Green, a quarter of a mile N.E. of Bledlow church.

At Horsenden it was seen in the ditch between two fields about a quarter of a mile west of the church and again on the road-side about a furlong S.E. of the church. It is also to be found in the bank by the side of the main road, south of Park Mill, the gradual change from dark green glauconite-sand to greenish-grey marl with scattered glauconite grains being here traceable.

In 1864 Mr. Whitaker saw a good section in a newly cut ditch along the road that runs north-west from Monks Risborough; by the railway about four feet of dark greensand was shown beneath a wash of chalky gravel, the greensand containing many brown nodules and yielding one indistinct fossil. Very few yards nearer the village there was glauconitic marl passing up into Chalk Marl with a few green grains. Similar glauconitic marl was seen at the entrance to the shallow railway-cutting N.E. of the bridge.

The like succession may be seen at the other end of the cutting near Great Kimble, the lowermost beds of the marl containing green grains, and a short distance further on dark green clayey greensand is seen passing down into greenish-grey sand with layers of hard calcareous sandstone, near the bridge is a soft bluish sandy clay or argillaceous silt.

Nothing more was seen of this bed for the space of over a mile, but it crosses the high road by the edge of the map N.E. of Bushey Leys, and in the bank here the following descending passage was seen in 1885:—Dark grey chalk marl passing down into glauconitic marl, the green grains being at first few and chiefly in nests, but in a breadth of some two feet becoming a bright green glauconitic marl; the marly element then gradually diminishes, its place being taken by very fine micaceous sand, so that the deposit becomes a yellowish green sand, the base of which is not seen.

### *Underground Range.*

Deep borings have proved the continuity of the Gault clays beneath the London Basin, and in four of those in our district there are stone beds comparable with those of the Upper Greensand, possibly in two others also. Whether the glauconitic marl that occurs above the Gault in the other borings is equivalent to the glauconitic sand above described (p. 53) is doubtful.

In the Richmond boring (see Well-sections) the lower part of the Gault consists of dark blue clays with nodules of iron-pyrites and many fossils, the upper part is a pale blue calcareous clay with few fossils. PROF. JUDD remarks that between these there appears to be "the most perfect and insensible gradation."\* A specimen of the Upper Gault clay taken from a depth of 1,026 feet from the surface, and 86 feet from the top of the Gault, contained nearly 33 per cent. of calcic carbonate.

The absence of layers of phosphatic nodules in the Gault below Richmond is noteworthy, the only such bed occurring at its very base.

Above the Gault at Richmond are beds of siliceo-calcareous rock, 16 feet thick. PROF. JUDD describes them as divisible into three, and says that the hard micaceous sandy rocks, which occur at the top and at the bottom "are quite indistinguishable in character and appearance from the well-known "Firestone" of Godstone. They contain respectively only 14.5 and 12.5 per cent. of calcic carbonate; the insoluble residue consisting of fine quartz-sand, mica, and glauconite."

The middle bed on the other hand "is softer and approximates in character to the Hearthstone of the Godstone pits, a typical specimen of which was found to contain 38 per cent. of calcic carbonate. The Richmond rock contains 19.5 per cent. of calcic carbonate, the insoluble residue containing less sand but more argillaceous matter than the beds above and below it.†

\* *Quart. Journ. Geol. Soc.*, vol. xl. p. 737.

† *Quart. Journ. Geol. Soc.*, vol. xl. p. 735.

In the Tottenham Court Road boring (see Well-sections) at the base of the Gault there is the usual layer of pebbles and phosphatic nodules, overlain by 2½ feet of clayey greensand, while the rest of the formation is clay with a few layers of phosphatic nodules. Overlying this came light-grey micaceous sandstone which PROF. PRESTWICH termed "firestone."

In the boring at Crossness (see Well-sections) the Gault was overlain by green sandy marl, without the intervention of anything like true Upper Greensand. The glauconitic marl is probably comparable to that which forms the base of the Chalk in Kent, between Maidstone and Folkestone, and which is certainly above the horizon of true Upper Greensand.

Passing now to the borings north of London we find a state of things very similar to that at Crossness, except that the Gault clay is much thinner. At Kentish Town (see Well-sections), it is evident that the greater part of the lowest mass of clay represents the Lower Gault of Folkestone, its upper part, together with the overlying beds, representing the Upper Gault of Folkestone and consequently a part of the Upper Greensand of other and more western localities. This Upper Gault was succeeded by green sand with grey clay, which may be compared with the dark green glauconitic sand found at the outcrops in Bucks., for the admixture of grey clay was probably carried down by the auger from the overlying Chalk Marl; even this 13 or 14 feet of clayey greensand may turn out to be strictly the base of the Chalk Marl rather than true Upper Greensand.

From the comparatively small thickness of Gault at Kentish Town one is led to think that this must be near one of the highest parts of the Palæozoic rocks, which were sinking beneath the Cretaceous sea, and it is noticeable that the other borings which have been made still farther north prove an increasing thickness of Gault for some distance.

The next deep boring within the district is that at Cheshunt (see Well-sections). In this the Gault is covered by undoubted Upper Greensand.

For the details of these beds in the Streatham boring, see Well-sections, where they are printed for the first time. As would be expected the Upper Greensand here is of the same lithological character as at the outcrop some miles to the south. The Gault is 188 feet thick, and of the usual character, with phosphatic nodules. From the thickness at the outcrop in Surrey, one would expect to find this clay a good deal thicker than under the central part of London, as was the case in the Richmond boring, and it is perhaps thinner here than one would have counted on.

The thickness of the Gault and of the Upper Greensand found in the deep borings is given in the tables above, pp. 42, 43. (W.W.)

### Fossils.

The following is a list of the fossils from the Gault and Upper Greensand in two of the above-mentioned borings, taken from the papers by PROF. PRESTWICH, MR. C. MOORE, and PROF. JUDD.\*

Gault Fossils.	Richmond.	Meux's well.
Fish-remains, and Coprolites	-	x
<i>Ammonites bouchardianus</i> D'Orb.	-	x
„ <i>interruptus</i> , Brug.	-	x
„ <i>lautus</i> , Sby.	-	x
„ <i>rostratus</i> , Sby.	-	x
„ <i>splendens</i> , Sby.	-	x
<i>Ancyloceras spinigerum</i> , Sby.	-	x
<i>Belemnites minimus</i> , Lister	-	x
„ <i>ultimus</i> , D'Orb.	-	x

\* *Quart. Journ. Geol. Soc.*, vol. xxxiv. pp. 912, 917, 918; vol. xl. p. 786.

Gault Fossils.			Richmond.	Meux's well.
Hamites armatus, <i>Sby.</i>	-	-	x	
" sp.	-	-	—	x
Dentalium medium, <i>Sby.</i>	-	-	—	x
Turbo	-	-	—	x
Inoceramus concentricus, <i>Sby.</i>	-	-	x	x
" sulcatus, <i>Park.</i>	-	-	—	x
Nucula	-	-	x	x
Ostrea	-	-	—	x
Pecten	-	-	—	x
Pinna	-	-	—	x
Ophiura	-	-	—	x
Pentacrinus Fittoni, <i>Aust.</i>	-	-	x	
Smilotrochus	-	-	—	x
Scalpellum magnum, <i>Darwin</i>	-	-	—	x
Many Entomostraca	{ See Mr. Moore's list Q.J.G.S. vol. xxxiv. pp. 917, 918. }		—	x
Many Foraminifera			—	x

## Upper Greensand Fossils.

Ammonites splendens, <i>Sby.</i>	-	-	—	x
Cuttle-fish hooks	-	-	—	x
Pecten interstriatus?, <i>Leym.</i>	-	-	x	
" orbicularis, <i>Sby.</i>	-	-	x	
Cythere concentrica, <i>Reuss</i>	-	-	—	x
" virginea, <i>Jones</i>	-	-	—	x
" new sp.	-	-	—	x
Cytherella Münsteri, <i>Röm.</i>	-	-	—	x
Paracypris, new sp.	-	-	—	x
Echini spines, etc.	-	-	—	x
Cristellaria acutaureolaria, <i>Fichter &amp; Moll</i>	-	-	—	x
" rotula, <i>Lam.</i>	-	-	—	x
Nodosarina raphanistrum, <i>Linn.</i>	-	-	—	x

## CHAPTER 5. CRETACEOUS BEDS (CHALK).

### GENERAL REMARKS.

The formation which is known to geologists as The Chalk includes more than the white earthy limestones which are so well known in this country as chalk and from which whitening and writing chalk are manufactured. Such limestones do make up the greater part of its thickness, but its lower portion includes beds of harder and more gritty limestone, and others of a marly nature; these are sometimes spoken of as "grey chalk" and "chalk marl." There are moreover certain harder and more compact beds which exhibit special and peculiar characters, such as the compact subcrystalline limestone to which the name of "Chalk Rock" has been given, the hard nodular stone termed "Melbourn Rock," and the blocky "Totternhoe Stone," which is used for building purposes.

The Chalk forms the surrounding and underlying rock of the whole of the London Tertiary Basin, beneath which, in our district, its thickness varies from 623 to about 700 feet.

Until the year 1880 the Chalk was generally divided into, Upper Chalk with flints, Lower Chalk with few or no flints, and Chalk Marl; the Chalk Rock being taken as the line of division between the Upper and Lower Chalk, and the Totternhoe Stone separating the Lower Chalk from the Chalk Marl.

In 1876 DR. CH. BARROIS published his "Researches on the Upper Cretaceous Formation of England and Ireland," and showed that the Chalk of England was capable of division into the same stages as those proposed by D'Orbigny for the Chalk of France, namely Cenomanian, Turonian, and Senonian.

The progress of the Geological Survey in Cambridgeshire, between the years 1876 and 1879, confirmed Dr. Barrois' conclusions and resulted also in the discovery that certain hard rocky beds formed a definite base to the Middle Chalk (or Turonian), were persistent over a large area, and had an outcrop which could be followed and mapped. This basal bed of the Middle Chalk was named the Melbourn Rock, and in consequence of its existence it was found possible not only to divide the Chalk for descriptive purposes into Lower, Middle and Upper divisions, but to show the limits of these divisions upon the Geological Survey map.\* The Chalk Marl alone had previously been separated, and in some parts only.

It was believed that the Melbourn Rock of Cambridgeshire would prove to be the same as the hard-bedded chalk previously noticed in Buckinghamshire.† This belief has proved to be correct.

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\* See *Geology of the Neighbourhood of Cambridge*, 1881, p. 20.

† *Quart. Journ. Geol. Soc.*, vol. xxi. p. 399; reproduced in *Geol. Surv. Mem.*, vol. iv.



These major divisions, like their equivalents in France, were found to be capable of subdivision into palæontological zones, which are bands, each including a certain thickness of chalk, distinguished by the presence or abundance of certain fossils, but not always sharply or definitely separated from one another. The same zonal divisions which were found to exist in Cambridgeshire have since been followed throughout the whole distance from that county to the north of Wiltshire and have also been determined at other places by Dr. Barrois and by Mr. W. Hill, so that there is little doubt that they extend over the whole of southern and eastern England, though they naturally vary somewhat in thickness at different localities.

The following tabular view of the classification now adopted by the Geological Survey, is substantially the same as that given in the Memoir on the Neighbourhood of Cambridge, though subsequent experience has necessitated some slight alterations, and the table also includes higher zones of Chalk than came under description in that Memoir.

Divisions.	Zones and Rock-beds.	Approximate Thickness.
Upper Chalk	{ Zone of <i>Marsupites</i> - - - - }	100
	{ Zone of <i>Micraster coranguinum</i> - - - }	300
	{ Zone of <i>Micraster cortestudinarium</i> - - - }	8
	{ Chalk Rock - - - - }	50
Middle Chalk	{ Zone of <i>Holaster planus</i> - - - - }	50-100
	{ Zone of <i>Terebratulina gracilis</i> - - - }	50-60
	{ Zone of <i>Rhynchonella Cuvieri</i> - - - }	4
	{ with Melbourn Rock at base - - - }	80
Lower Chalk	{ Zone of <i>Belemnitella plena</i> - - - - }	60-120
	{ Zone of <i>Holaster subglobosus</i> - - - }	
	{ with Totternhoe Stone at the base - - - }	
	{ Zone of <i>Ammonites varians</i> - - - - }	

One of the modifications above alluded to is the separation of the zone of *Belemnitella plena* from the Melbourn Rock and its inclusion in the Lower Chalk. Another is the separation of the Chalk Rock from the Middle Chalk, as the top of which it was formerly regarded; sections on this horizon, seen in the counties of Buckingham and Oxford, have made it doubtful whether it is more intimately connected with the Middle or with the Upper Chalk, and it has been thought better to give the rock and the beds immediately overlying it an independent position for the present, until more is known about the remarkable assemblage of fossils they contain.

A third change is in the choice of a characteristic fossil to denote the lowest zone of the Lower Chalk. *Ammonites varians* has been used by other writers for this purpose, or for denoting portions of this zone; but when the Cambridge Chalk was examined a few specimens of this species were found at an horizon which was believed to be above the Totternhoe Stone, and we were not then sure that it might not be of common occurrence

throughout the Lower Chalk. Further experience, however, has shown that this is not the case, and that the fossil is abundant in and characteristic of the beds below the Totternhoe Stone, only occurring rarely in that stone or in the beds above it. In Berkshire, indeed, this relative abundance of *Ammonites varians* is so marked that the Chalk Marl (or the chalk below the horizon of the Totternhoe Stone) might be distinguished from the overlying beds by this means over the tracts where the outcrop of the stone cannot be followed.

The succession of the various divisions at the great escarpment is shown by Fig. 2, which is a corrected version of the "General Section near Risborough," by Mr. Whitaker, originally published in 1865, and given as Fig. 6 of the Geological Survey Memoirs, vol. iv.

### LOWER CHALK.

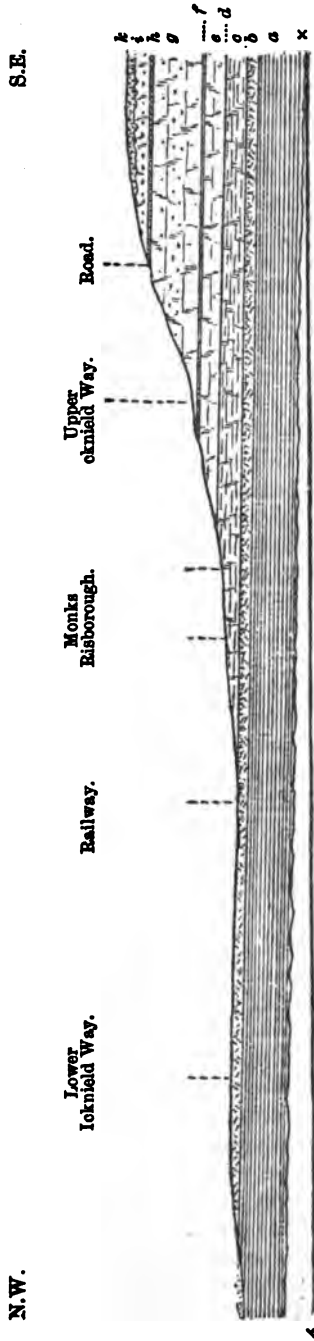
#### *General Description.*

This division includes the beds which are generally known as Chalk Marl and Grey Chalk, and when the limits of the Lower Chalk in its present restricted sense were first defined, in 1880, I sought to fix the application of the term Grey Chalk, which had previously been very loosely used, by employing it for the whole upper portion of the Lower Chalk. This however has not proved very satisfactory, for the beds which underlie the Belemnite-marls are always white and it is really only the central part of the division which could with any propriety be called Grey Chalk. The Totternhoe Stone is certainly Grey Chalk, and beds which are lithologically grey chalk occur in the Chalk Marl. In view of these considerations it will perhaps be best to avoid the use of the terms Chalk Marl or Grey Chalk as constituting definite subdivisions of the Lower Chalk, and to employ the zonal nomenclature for this as for other portions of the Chalk. At present three zones are recognised in the Lower Chalk.

The Zone of *Ammonites varians* consists in the lower part of soft grey marl with some bands of tough sandy marl, this portion being apparently about 30 feet thick. Above it is a band of compact greyish chalky limestone which might locally receive the name of the "Marl Rock." It somewhat resembles the Totternhoe Stone when weathered but when freshly exposed it is much harder, more compact and blue-hearted; the fossil contents are also different, the species *Rhynchonella mantelliana*, *Kingena lima*, *Pecten orbicularis* and *P. fissicosta*, so abundant in the Totternhoe Stone, do not occur, their place being taken by *Ammonites varians* and *Inoceramus latus*, which are essentially Chalk Marl species. There are sometimes two bands of such rock, from 3 to 4 feet thick, with marl between. It is par excellence the water-bearing stratum of the district where it comes to the surface, its outcrop being marked by a line of frequent springs most of which are utilised for the growth of water-cress.

The Marl above these rocky beds appears to be more compact than that below and there must be between 30 and 40 feet of such marl between the Marl Rock and the Totternhoe Stone, but just below the latter there are some few feet of soft shaly marl.

Figure 2. Section through Monks Risborough and the neighbouring Chalk Escarpment.



Horizontal scale 3 inches to a mile. Vertical scale twice as great (880 feet to an inch).

x x. Ordnance Datum.

- k. Clay with flints.
- i. Upper Chalk.
- h. Chalk Rock.
- g. Middle Chalk.
- f. Melbourn Rock.

- Lower Chalk {
  - e. Zone of *Holaster subglobosus* (blocky Chalk), with
  - d. Totternhoe Stone at the bottom.
  - c. Zone of *Ammonites varians* (Chalk Marl).
- b. Upper Greensand.
- a. Gault.

The representative of the *Totternhoe Stone* is a grey gritty stone, weathering into thin platy beds and containing many small phosphatic nodules; it does not exceed 3 feet in thickness, does not make any feature at its outcrop, and passes up into tough grey slightly gritty chalk.

The mass of the *Zone of Holaster subglobosus* is compact and blocky without any definite bedding, and of a dull greyish-white. At the north-eastern edge of the map (Sheet 7) it includes a remarkable bed of hard grey gritty chalk 2 feet thick, very similar to Totternhoe Stone, but full of large impure phosphatic nodules which are greenish or yellowish outside. The chalk above this passes up into a hard white compact chalk, the microscopical structure of which is different from that of the grey chalk below.

The *Zone of Belemnitella plena*, which is the topmost bed of the Lower Chalk, consists of soft shaly argillaceous marl, generally inclosing a band of hard white limestone.

#### *Description of Sections.*

Near Winnall, south-west of Bledlow, a road-cutting shows soft grey shaly marl overlain by about 3 feet of hard grey shaly stone (Totternhoe Stone) containing many phosphatic nodules, with *Ammonites varians*, *Rhynchonella mantelliana* and *Terebratula semigiobosa*; this passes up into tough grey chalk, slightly sandy but without any nodules. The same bed of stone was formerly seen by Mr. Whitaker below the chalk-pit south of Bledlow, the chalk in the pit being tough, blocky and with large *Ammonites* (*Am. sussexensis* and *Am. lewesensis*?).

At Bledlow, on the eastern side of the church, there is a deep dell formed by springs which issue from the rocky beds in the Chalk Marl. This dell is about 25 feet deep and one band of firm marly chalk occurs about a third of the way down, while at the base there is a very hard greyish sandy rock, out of the joints of which several springs of clear water issue. By the springs the rock is decomposed into a soft and sandy mass, but away from the water it is hard and contains *Ammonites varians* &c. The level of this rock must be at least 40 feet below the Totternhoe Stone. Of this hollow Mr. Whitaker remarks:—Notwithstanding the water-cress beds, which far from improve it, this embryocombe is very pretty. The little hollows in its western side, their clear bright springs spouting out from the green-clad sides (sometimes with the moss and other plants encrusted with a calcareous coat from the trickling water) with here and there a patch of bare whitish marl, need but the sun lighting up the old church and glancing through the leaves of the tall overhanging elms to complete the picture. Below this the stream runs in a deeply cut channel, in which a hard bed makes a wee waterfall. There is a specimen of the calcareous deposit in the Museum at Jermyn Street, the plant mostly found being *Marchantia polymorpha*.

The same rock-bed is to be seen at the spring-head S.W. of Saunderton and again in the railway-cutting south of Risborough Station; here there seem to be several beds of rock, but the uppermost on the southern side of the bridge is the best exposed and from it most of the fossils mentioned on pp. 64, 65 have been obtained.

The Chalk above the Totternhoe Stone is exposed in a small pit half a mile S.E. of Saunderton and traces of the noduliferous stone itself were found by the roadside 3 furlongs S.S.E. of the church, and more clearly in the roadway N.E. of Culverton, where 3 or 4 feet of hard grey stone was seen containing phosphatic nodules with *Rhynchonella mantelliana* and *Kingena lima*; below was soft grey sandy marl, and a small pit above showed tough greyish-white blocky chalk. Another exposure occurs in an old pit at Parkfield, barely half a mile south of Risborough church, where the blocky chalk may be seen passing down into hard grey sandy stone, full of phosphatic nodules and about 2 feet thick.

The spring east of Culverton probably rises from the Totternhoe Stone, but it is generally dry in the summer, while the strong springs near Princes Risborough rise from the lower rocky bed in the Chalk Marl. There is in fact a line of springs rising from this rock for some distance on either side of Princes Risborough, and as the spring-heads are all cleared out and utilised for the growth of watercress the rock can be examined in all of them. At Monks Risborough there are two springs, one S.W. and the other N.E. of the church, and the thickness of the rock appears to be from 4 to 5 feet; at the south-western spring the layer of rock forming the floor of the pool was proved, with a crowbar, to be about a foot thick, the bar then passing into soft marl. A thickness of 3 feet of the hard stone was seen in the bank, from which were obtained *Inoceramus latus* (abundant), *Ammonites varians* (abundant), *Ammonites Mantelli*, *Turrilites tuberculatus*, *Rhynchonella grasiiana*, and other fossils (see list, pp. 64, 65).

Other springs occur at Ascott, but no exposure of the Totternhoe Stone was seen. There are however two pits in the overlying blocky chalk, one 5 furlongs E.N.E. of Monks' Risborough, and another the same distance from the middle of Ascott, but neither presents any features of interest.

The old pit just east of Great Kimble church must formerly have exposed a fine section of the Lower Chalk, including the Totternhoe Stone and some depth of the Chalk Marl. Mr. Whitaker speaks of the browner tint of the latter two as contrasting with the white of the overlying chalk. The outcrop of the Totternhoe Stone can still be seen, but the section is obscured by falling debris. The stone is also exposed in a small cut by the side of the pathway leading to the combe, in which are the springs that issue from the rock-bed in the underlying marl, and pieces of this occur in the bank at the foot of which the springs gush out.

At Ellesborough there is a small pit in the higher beds of the Lower Chalk: the Totternhoe Stone crops out near the base of the hill and the springs below rise from the lower bed of rock in the Chalk Marl; an upper bed of similar rock can be seen in the lane about 350 yards N.E. of the church.

The Totternhoe Stone, very thin but containing the usual nodules and fossils, can be seen at Butlers Cross, by the entrance of the road to Combe; while the chalk-pit on the eastern side of this road gives the following section:—

		FEET.
Soil		— $\frac{1}{2}$
Middle Chalk	Thin-bedded Chalk with a few nodules	1 $\frac{1}{2}$
	Marly chalk with loose nodules, and with a layer of hard white compact rock	1 $\frac{1}{2}$
	Hard yellowish rough nodular rock, in two beds, separated by a layer of soft greenish-grey marly chalk	3 $\frac{1}{2}$
	Laminated marly chalk	— $\frac{1}{2}$
	Hard whitish rock, with many layers of small nodules; in three beds	5
	Soft grey laminated marl	$\frac{3}{4}$ to 1
Lower Chalk	Hard compact white chalk, thinning southward	0 to 1
	Soft grey clayey shaly marl, thickening eastward	$\frac{1}{2}$ to 1 $\frac{1}{2}$
	Hard rough gritty rock, mottled white and grey, passing down into the next	1 $\frac{1}{2}$
	Hard white chalk, very firm and compact, though somewhat brittle, not bedded, breaking into massive angular blocks with smooth surfaces	9
	Parting of shaly marl.	
	Hard grey chalk in massive beds	5
	Hard grey sandy chalk with green grains and scattered green-coated nodules	2 $\frac{1}{2}$
	Hard grey chalk, seen for	3

The total thickness from the Totternhoe Stone to the marl bands below the Melbourn Rock is not much more than 50 feet, and of this at least 40 feet belong to the lower or grey part of the *Holaster subglobosus* zone.

Under the microscope the matrix of the nodule-beds is seen to consist largely of shell-fragments among which green grains and foraminifera are scattered: the nodules are of all sizes up to that of a large potato; internally they are pale yellowish-brown or buff, but generally have a greenish outer coating, the outer portion is moreover riddled with small tubules which do not penetrate far into the nodule, and are filled with the chalky matrix. These nodules have the appearance of chalk which has been hardened by an infiltration of phosphatic matter.

The upper portion of the zone has a microscopical structure of the kind described in the note by Mr. HILL (*post.*), coccoliths being very abundant. The uppermost 10 or 12 inches of this chalk has a peculiar structure, being very hard and marbled or veined with a grey material, of which in some places there is more than of the white chalk, but the rock breaks through both, so intimately are the two mingled. In the mottled rock I found a small specimen of *Belemnitella plena*.

A fault-plane, with slickensides, filled with marly rubble, strikes obliquely across the pit, but almost parallel to the exposed face; its throw could not be ascertained, but seemed not to be great, probably it has been caused by a slip down the escarpment, which here trends back into the Combe Valley.

The upper surface of the white chalk is slightly undulating and uneven, and upon it rests the soft grey marl of the overlying zone. At the southern end of this section there is one continuous bed of marl about 2 feet thick, the upper part greyish-buff, shaly and gritty, but darker and more clayey at the base. It consists in fact of the upper and lower marls united and in a few yards northward the usual compact rock is seen coming on as a thin wedge, separating the marl into two layers. The rock however is greyer and more gritty than usual; it thickens northward to about a foot and at the same time shaly beds come in below (see fig. 3) and apparently fill up a broad shallow hollow in the underlying chalk, the layers *b* and *c* being here 18 inches thick; in them I found a large Ammonite (*Am. peramplus* or *lewesiensis*), *Ostrea vesicularis*, and portions of two *Belemnitella plena*, one large and much rolled. The upper marl yielded *Ostrea vesicularis*, *Inoceramus mytiloides* and *Rhynchonella plicatilis*.

Figure 3. Section in a Chalk Pit at Butlers Cross.



Grey sandy chalk, apparently not far above the Totternhoe Stone, is visible by the side of the road to Wendover half a mile from Butlers Cross. The Well Head spring at Wendover rises from the Totternhoe Stone, pieces of which are thrown out of the water-course. In the road-cutting east of the church there is whitish chalk.

### Fossils.

The fossils mentioned in the following list, which shows the range of the species found in the several portions of the Lower

Chalk, were chiefly collected by MR. J. RHODES, but I had collected from some of the localities and had in a few cases found species that did not subsequently fall under Mr. Rhodes' hammer. The species found by him were determined by MESSRS. SHARMAN and NEWTON, but for the identification of the remarkable sponge (*Phymatella intumescens*) I am indebted to DR. G. J. HINDE, who informs me that it has not been recorded before from the English Chalk, and in Germany is only known from the Middle and Upper divisions (Turonian and Senonian).

The localities for the rock bed in the Chalk Marl are indicated by figures, which refer to the following exposures:—1, the railway-cutting south of Princes Risborough Station; 2, the spring head at Princes Risborough; 3, the springs at Monks Risborough; 4, the springs at Ascott.

The localities for the Totternhoe Stone are:—A, the road-cutting at Winnall, S.W. of Bledlow; B, the road-cutting N.E. of Culverton; C, the pit at Parkfield.

The localities for the chalk above the Totternhoe Stone are pits:—a, south-west of Bledlow; b, half a mile south-east of Saunderton; c, near Whiteleaf; d, half a mile south-east of Great Kimble; e, at Butlers Cross.

The only locality where fossils were obtained from the zone of *Belemnitella plena* was the pit at Butler's Cross.

			Rock bed in Chalk Marl.	Totternhoe Stone.	Chalk above Totternhoe Stone.	Zone of <i>Bel. plena</i> .
<i>Spongida.</i>						
Brachiolites	-	-	1 . 3 4			
Phymatella intumescens, Röm.	-	-	1 . 3			
<i>Crustacea.</i>						
Enoplocyrtia	-	-	. . . .	. . . .	. b	
Pollicipes	-	-	1			
<i>Echinodermata.</i>						
Cidaris hirundo, Sorig	-	-	. . . .	. . . .	. . . . .	x
Hemiaster Morriai?, Forbes	-	-	. . . 3			
Holaster laevis, Mant.	-	-	. . . .	. . . .	a . c	
„ trecensis, Leym.	-	-	. . . .	. . . .	. . c d e	x
<i>Brachiopoda.</i>						
Kingena lima, DeFr.	-	-	. . . .	. . C		
Rhynchonella Cuvieri, D'Orb.	-	-	. . . .	. . .	. . c d .	x
„ grasiana, D'Orb.	-	-	. . . 3			
„ mantelliana, Sby. (type)	-	-	. . . .	A . C		
„ ? (var.)	-	-	. . . .	. . .	. . . . .	x
„ Martini, Mant.	-	-	1 . 3			
„ plicatilis, Sby.	-	-	. . . .	. . .	. . . . .	x
Terebratula semiglobosa, Sby.	-	-	. 2	A B C	a . c . e	x
Terebratulina gracilis, Schloth.	-	-	. . . .	. B		
„ striata, Wahl.	-	-	. . . .	. . .	. . c . e	

			Rock bed in Chalk Marl.	Tottenhoe Stone.	Chalk above Tottenhoe Stone.	Zone of Bel. plena.
<i>Lamellibranchiata.</i>						
<i>Exogyra halioidea</i> , Lam.	-	-	. . . . .	. . . . .	. b c d	
<i>Inoceramus Cuvieri</i> ? Sby.	-	-	. . . . .	. . . . .	. . c d e	
" <i>latus</i> , Mant.	-	-	1 2 3 4	. . . . .	a . . . .	x ?
" <i>mytiloidea</i> , Mant.	-	-	. . . . .	. . . . .	. . . . e	x
" <i>striatus</i> , Mant.	-	-	. . . . .	. . . . .	a . c d	
<i>Lima globosa</i> , Sby.	-	-	. . . . .	A . . . .	. . . c	
<i>Ostrea normaniana</i> , D'Orb.	-	-	. . . . .	. . . . .	. . . . .	y
" <i>vesicularis</i> , Lam.	-	-	. . . . 4	A B . . .	a . c d e	x
<i>Pecten Beaveri</i> , Sby.	-	-	. . . . .	. . . . .	. b	
" <i>orbicularis</i> , Sby.	-	-	1 . 3 .	. . . . .		
<i>Plicatula inflata</i> , Sby.	-	-	1 . 3 .	A . . . .		
<i>Cardita tenuicosta</i> , Sby.	-	-	1 . 3 .	. . . . .		
<i>Cucullea carinata</i> , Sby.	-	-	1 2 3 .	. . . . .		
" sp.	-	-	. . . . .	. . . . .	. . . . .	x
<i>Nucula</i>	-	-	. . . . .	A . . . .		
<i>Gasteropoda.</i>						
<i>Aporthais</i>	-	-	1 2	. . . . .		
<i>Cinulia</i>	-	-	1 . 3	. . . . .		
<i>Solarium</i>	-	-	. 2	. . . . .		
<i>Trochus</i> ?	-	-	. . 3	. . . . .		
<i>Turbo</i>	-	-	. 2	. . . . .		
<i>Cephalopoda.</i>						
<i>Ammonites Cunningtoni</i> , Sharpe	-	-	. . . . .	. . . . .	a . . . .	
" <i>lewesiensis</i> , Mant.	-	-	. . . . .	. . . . .	. . . . .	x
" <i>navicularis</i> , Mant.	-	-	. . . 3	. . . . .		
" <i>rotomagensis</i> , DeFr.	-	-	. . . . .	A . . . .	a . . . .	
" <i>varians</i> , Sby.	-	-	1 2 3 4	. . . . .		
" " (in phosphate)	-	-	. . . . .	A . . . .		
" " (var. Coupei)	-	-	1 2 3 4	. . . . .		
" sp.	-	-	1	. . . . .		
<i>Belemnites plena</i> , Blainv.	-	-	. . . . .	. . . . .	. . . . e	x
<i>Turritites Mantelli</i> , Sharpe	-	-	1	. . . . .		
" <i>tuberculatus</i> , Bosc.	-	-	1 . 3	. . . . .		
<i>Fish.</i>						
<i>Corax heterodon</i> , Reuss	-	-	. . . . .	. . . . .	. . c	
<i>Lamna gracilis</i> , Pict. & Camp.	-	-	. . . . .	. . . . .	. . . . e	
" <i>subulata</i> , Ag.	-	-	. . . . 4	. . . . .		
<i>Protosphyraena ferox</i> , Leidy	-	-	. . . . .	. . . . .	. b	
<i>Elasmobranch vertebra</i>	-	-	. . . . .	. . . . .	. . . . .	x
<i>Fish scales</i>	-	-	. . . . .	. . . . .	a . . d .	x

## MIDDLE CHALK.

*General Description.*

This division consists of three substages or zones (see p. 58), the middle of which includes the larger part of the division, the



top one being crowned by the hard compact limestone known as the Chalk Rock.

*The Melbourn Rock* is a hard nodular limestone, in massive beds when quarried, but weathering into hard nodular lumpy layers near the surface; the lower beds often have a greenish white tint and the upper beds are yellowish. The rock consists of a compact matrix with lines of small lumps or nodules which are white inside. From its hardness the feature made by the outcrop is generally well-marked and forms a very irregular line running in and out of the deep combs and valleys which furrow the escarpment.\* The thickness may be taken at 9 or 10 feet, but the rock passes up into hard yellowish bedded chalk, the small nodules becoming fewer and fewer and the chalk more firm and compact. Fossils are rare in the rock itself but *Rhynchonella Cuvieri* is abundant in the beds which form the upward passage. The higher beds of the zone consist of rather hard bedded chalk in which *Inoceramus mytiloides (labiatus)* is very abundant, this chalk indeed being largely composed of the broken fragments of these shells. *Rhynchonella Cuvieri* and *Holaster subglobosus* are also common; while *Discoidea minima* and *Cardiaster pygmaeus* occur in some localities. Single flints are occasionally found in the upper beds.

*The Zone of Terebratulina gracilis* consists for the most part of soft white chalk, in which the bedding would be hardly apparent were it not for frequent thin seams of soft greyish-white marl. Flints of various sizes occur in planes but at a considerable distance apart, and are always black-centred. This zone forms the greater part of the steeper slopes of the escarpment and may be about 120 feet thick. *Holaster subglobosus* is common in the lower beds, *Spondylus spinosus* and *Inoceramus Brongniarti* in the upper beds, but the zone is nowhere highly fossiliferous.

*The Zone of Holaster planus* consists of firm white chalk with seams of marl like those in the zone below, but there is generally an absence of flints.

At least 30 or 40 feet of chalk may be referred to this zone, but fossils are seldom found in these upper beds, and there is a complete passage both downwards into the underlying zone and upwards into a rough hard nodular chalk, which in turn passes up into the hard cream-coloured limestone of the Chalk Rock.

### *Description of Sections.*

#### *Zone of Rhynchonella Cuvieri.*

Below the steep escarpment of the Bledlow Hills the feature of the Melbourn Rock is hardly distinguishable and the whole outcrop of the Middle Chalk is reduced to a narrow strip along the hill-side. When it curves round to enter the Wycombe Valley it widens out considerably, but no sections in the lower

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\* For a fuller account of this rock and its structure over a larger area, see W. HILL and A. J. JUKES-BROWNE, in *Quart. Journ. Geol. Soc.* vol. xlii, pp. 216-231 (1886).

beds of this division were seen, and the line of the basement-rock was traced, partly by fragments on the surface and partly by feature, to the cutting on the high road three furlongs south of Culverton. Here the base of the rock and part of the underlying zone of *Belemnitella plena* can be seen in the bank, and the rocky beds are also traceable in the road to the north-east.

Opposite the farm called Brimmers there is a small pit exposing the following beds—

	FEET.
Soil and rubble	2
Melbourn Rock { Hard nodular rock weathering into slabs	4
{ Hard rough nodular rock, greenish in places	2
Zone of <i>Belemnitella plena</i> . { Soft grey marl and marly chalk	1

Some of the same beds are also exposed by the roadside north-west of the farmstead, and the feature made by them to the westward is very distinct. A few feet of the rock can be seen in the road-cuttings at Whiteleaf N.E. of Princes Risborough and the outcrop can be readily traced by Cadaden, Kimble and Combe, as the rock caps all the projecting knolls and ridges that intervene between the deep combes of this district.

The pit at Butler's Cross, south of Chalkshire, gives an excellent section of the rock (see p. 62), the uppermost bed of which, enclosing a layer of compact chalk without nodules, is a local peculiarity.

East of this place the feature made by the Melbourn Rock retires to the base of the steep slope below Bacombe Hill; some of the rock can be seen in the road-cutting west of Wendover, and the upper part of the *Rhynchonella Cuvieri* zone is exposed in the pits at the eastern end of Bacombe Hill.

South of Wendover the rock again makes a prominent feature and can be seen overlying the yellow marl of the *Belemnitella plena* zone in the cutting at the entrance of the lane a quarter of a mile S.E. of the Well Head. Returning along the northern side of this valley the outcrop curves round the base of Bodlington Hill and then passes northward out of the district.

#### *Zone of Terebratulina gracilis.*

This part of the Middle Chalk is but seldom exposed within the area of the map (Sheet 7), the following being the only two localities where it was observed:—Two small pits, in compact white chalk, on Lodge Hill one mile south of Saunderton, and the road-cutting between Coombe and the Chequers, two miles S.W. of Wendover.

#### *Zone of Holaster planus.*

The chalk of this zone is exposed at several localities immediately beneath the Chalk rock, the local details are therefore given under the heading of that rock in order to avoid repetition, see especially pp. 70-72.

### CHALK ROCK AND MICRASTER BEDS.

#### *General Description.*

The bed to which the name of "Chalk Rock" was given in 1859\* is a hard cream-coloured limestone containing green glauconite grains and layers of irregular green-coated nodules which probably contain a certain amount of phosphatic matter; this rock breaks with a clean even fracture and rings when struck with the hammer.

There is often a thickness of 4 or 5 feet of such rock passing downwards into hard lumpy chalk, which graduates into the firm white chalk below: the upper surface of the rock is generally a well

\* W. WHITAKER, in "Catalogue of Rock Specimens in the Museum of Practical Geology," Ed. 2, p. 296.

marked plane, because it coincides with a layer of green-coated nodules, but the green grains extend into the chalk above, which generally consists of hard rocky lumps in a matrix of soft dull-white mealy chalk. Of this lumpy or rubbly chalk there is generally a thickness of 12 or 15 feet, and fossils are abundant in it, *Micraster cortestudinarium*, *Ananchytes ovatus* and *Rhynchonella plicatilis* being the commonest; indeed from the abundance of *Micrasters* it may well be called "the Micraster Bed."

At the summit of this Micraster Bed there is generally a second bed of "Chalk-rock" similar to that below and containing some of the same fossils, but never so thick.

The above is the normal constitution of this passage-zone, but sometimes the whole consists of a succession of rocky layers, each composed of hard lumpy chalk, passing up into yellowish rock with a layer of green-coated nodules at its top. When it assumes this form fossils are never so abundant as when it exhibits only two more solid layers enclosing the Micraster Bed.

The hard limestone beds are always full of Sponge remains, as may be inferred from their microscopical structure (see *post*), but the sponges themselves are not always in a recognisable form. Sometimes long tubular holes appear in the rock, giving it the appearance of having been bored by lithophagous Molluscs, only that the hollows are deeper and more irregular than those of boring Molluscs; I believe these to be the spaces occupied by certain species of tubular sponges, resembling that known as "Venus' Flower-basket," for where the rock is unweathered, softer portions, consisting of powdery chalk amongst which fragments of sponge occur, are often discernible; such portions of the mass would be the first to yield to solvent agencies, especially near the surface, where roots of plants assist in the process: it is generally beneath wooded country that the holes are most conspicuous.

It is this hard rock which protects the steep slope of the escarpment, and thus largely helps in giving rise to the well-known scenery of the Chiltern Hills. The outcrop of the rock does not, like that of the Melbourn Rock, follow the general direction of the line of strike, but is diverted down the wide and picturesque valleys which trench the escarpment; and, as the dip of the chalk is very little greater than the slope of the valley-bottoms, it runs a long way down the main valleys and a long way up each of the tributary valleys which open into them.

### *Detailed Description.*

#### *Main Escarpment on the west.*

The boundary of the Chalk Rock enters the map nearly two miles south-west of Bledlow church, at a height of over 700 feet above the sea. The lowermost beds are exposed in a small pit near the county-boundary about a mile S.W. of Bledlow, as follows:—

Weathered lumpy chalk; 4 feet.

Hard compact limestone, yellowish, with green grains, and traversed by ramifying tubular hollows; 2 feet.

Rough nodular chalk, seen for 1½ feet.

At the top of the rock bed there is a layer of large green-coated nodules, from which many fossils were obtained by Mr. RHODES (see list on p. 73) The chalk below contains *Ventriculites*.

#### *Loudwater Valley.*

The outcrop of these rock-beds makes a noticeable feature on Thickthorn Hill, thence passes southward through Great Wood and Frenches Wood to Bledlow Chapel, and runs out on either side of the long narrow tongue of Upper Chalk which is known as Bledlow Ridge. At the end of this, where the road begins to descend the hill, there are small excavations in the bank, which combine to give the following succession :

Chalky soil and rubble.

Thin rocky layer with green grains and yellowish lumps, hardly to be called nodules.

Soft chalk, weathering to a buff powder and containing hard nodular lumps; Echinoderms abundant (*Micraster*, *Ananchytes* and *Holaster*); about 10 feet.

Floor of hard compact chalk-rock with green grains and a layer of green-coated nodules.

East of this point there is a long narrow isolated ridge, extending from near Bottom Farm to West Wycombe and showing Chalk Rock capped by a certain amount of Upper Chalk, the former cropping out in the woods along the slopes which are too steep for cultivation. The rock can be seen in the cutting for the foot-path through Allnutts Wood, east of Bottom Farm, and again near the entrance to the cave above West Wycombe. At the latter place the main bed is 2 feet thick, a compact limestone with many green grains and green-coated nodules, having a marked plane of separation at the top, immediately above which is a course of flint nodules. About four feet below its base is a layer of hard nodular and less compact rock. The ridge ends here in a very steep slope, which is dotted with some fine old yew trees and crowned by the old earthwork, in the midst of which stands St. Lawrence's church, at a height of 240 feet above the roadway through the village below.

Down the valley (S.E.) Mr. Whitaker originally recorded the following exposures:—About a mile and a half above High Wycombe, in the lane at the southern corner of the small park called "Plummer's Hill," the Chalk Rock contains many black grains, harder than the Rock itself and standing out on the surface; there is Chalk-with-flints above. It occurs in a chalk-pit on the hill-flank just outside of High Wycombe, on the N.W.; and in another west of Upper Marsh Hill, S.E. of the same town, where it is more than five feet thick, but less compact and jointed than in the country to the west, and has a bed of flints resting at once on it. The railway-cutting S.W. of Wycombe Marsh is in the Middle Chalk, without flints; at the top, and for a short distance along the road to the south, the Chalk Rock is shown: it is irregular in structure and not hard throughout, beds of hard cream-coloured rock with nodules alternating in fact with beds of chalk; there is full seven feet between the top and bottom beds of the rock, which is not jointed, but breaks up into small pieces; higher up the road the Chalk-with-flints comes on. The Chalk Rock, overlain by the Chalk-with-flints, may again be seen in the cutting on the road that crosses the railway a little S.E. of the above. It probably crops out for some way up the Hughendon Valley, which joins that of the Loudwater at Wycombe.

Returning to West Wycombe the outcrop of the Chalk Rock is traceable along the fields and slopes east of the village and through the woods to the east and north of Bradenham, but no exposure of any importance was seen till about where the valley opens out to the escarpment.

#### *Escarpment between the Loudwater and Misbourn Valleys.*

On the road leading to the hamlet called The Sprat, at the southern end of Loosely Row, the outcrop of the rock is seen about half way down the slope of the hill, in a small quarry by the roadside, the section being as follows:—

- Chalk { Loose weathered nodular rock ; 2 feet.  
 Rock { Very hard compact yellowish limestone, with a layer of large  
 green-coated nodules at the top and others included ; a foot,  
 passing into the next.  
 Hard nodular chalk which is softer below ; 3 feet.  
 A lower excavation shows soft white chalk for several feet.

The rock can be seen by the roadside at the northern end of Loosely Row, and again near the bottom of the cutting on the road leading up the hill to Paralows. Thence the outcrop sweeps round the heads of several combes and runs out to the promontory of Risborough Hill, which presents a fine escarpment to the west. At the southern end of the hill and about a mile east of Princes Risborough church a pit by the roadside gives the following section :—

		Ft.	In.
Chalk Rock	Rough nodular rocky chalk (at one corner)	3	0
	Yellow-green-coated nodules	—	2
	Light-buff chalk, smooth and homogeneous but containing hard concretionary lumps	3	0
	Green-coated nodules	—	2
	Rough nodular chalk	2	6
	Large yellowish nodules, forming the top of a bed of hard nodular cream-coloured limestone	—	1 0
	The above passes down through less nodular rock, about a foot in thickness, into smooth soft and homogeneous white chalk, of which 4 feet are seen	—	5 0

In the rough nodular chalk at the top I found *Holaster planus*, *Micraster*, *Ammonites Prosperianus* and *Terebratula carnea*. In the lower beds fossils were rare and I could only find *Terebratula semiglobosa*, *Spondylus spinosus*, *Inoceramus*, *Pleurotomaria* (a cast), and the cast of a small coral (*Parasmilia*).

At this exposure there are more layers of green-coated nodules than occur elsewhere in the district. In another pit, at a little lower level, a thickness of about 10 feet of the underlying thick-bedded and blocky white chalk is exposed.

Hard compact rock can be seen at the top of the large triangular base of Risborough Cross, which is cut out of the green turf on the hill-side and is "scoured" every year, like the similar memorial in the Vale of the White Horse. The hill above is a narrow spur, on the eastern slope of which fragments of hard rocky chalk are abundant.

#### Misbourn Valley.

From Risborough Hill the boundary of the Chalk Rock runs eastward and south-eastward along the southern side of the Hampden valley, which joins that of the Misbourn at Missenden. The line of outcrop along this tract has been drawn chiefly by contour, on the six inch map, checked at a few places by small exposures of the rock-beds, as at Solinger Farm, two miles east of Princes Risborough, and by the road in Hampden Park, two furlongs east of the House. For exposures on the northern side of this branch-valley see p. 71.

On the right side of the main valley the outcrop of the rock can be seen in the lane about half a mile south of the Nag's Head. Mr. Whitaker was informed that two beds of the rock had been found in sinking for chalk at the brickyard on Hyde Heath, about 1½ miles east of Missenden.

South-eastward, down the valley, its outcrop was noticed by Mr. Whitaker as far as Amersham. In sinking for chalk in parts of Penn Wood, between Amersham and High Wycombe, the Chalk Rock has been found at a depth of from 40 to 50 feet, but has not been sunk through, by reason of its hardness. The rock was seen, on the other side of the valley, on the high road just east of the mill at the eastern outskirts of Amersham, and also on the road up the hill north of the town.

At Great Missenden a good section of the whole zone and of its junction with the Upper Chalk is found in the chalk-pit by the roadside 300 yards north of

the church, but the upper part was inaccessible at the time of my visit (1885) and the figures given below are estimates only.

	FEET.
Soil and rubble - - - - -	2
Rocky layer with yellowish nodules, overlying rough nodular chalk with other layers of nodules -	6½
Nodular rocky chalk, hard at the top -	1½
Hard yellowish compact rock, weathering into nodular masses, with a layer of brownish phosphatic nodules at the top - - - - -	1
Soft white chalk in massive beds - - - - -	7
Soft chalk lying between two thin marly layers -	2
Soft white chalk in thick beds with a marly layer near the bottom - - - - -	20

Northward of Missenden a good section of the rock is exposed in a pit at the corner of the wood east of Havenfield Lodge. The base is here more accessible than at Missenden, but the only fossils obtained were *Ventriculites decurrens*, and *Ostrea normaniana* from the line of phosphatic nodules at the top of the lowest rock bed.

The two thin layers of marl in the underlying chalk here occur again at the same distance below the rock, and they are seen also in the excavations by the side of the lane leading from Wendover Dean to Bowood, but the rocky beds are not exposed there; neither could they be found in the road-cutting west of Kings Ash, although it is pretty deep at the level where the outcrop should occur.

#### *Escarpment eastward of Wendover.*

In the green lane or foot-path west of Jenkins Hill Mr. Whitaker saw two beds of the rock about 12 feet apart; this section is now much grown over but I found a bed of very hard compact cream-coloured limestone cropping out beneath the roots of the bushes; this bed did not seem to be more than a foot thick and the weathered blocks are pierced by the long irregular branching holes which have been previously described and which at first sight look very like *Pholas* borings. A block of this rock with tubular holes is deposited in the Museum at Jermyn Street.

The same bed is seen again in the road-cutting east of The Hale and in the old limekiln on the southern side of the road, where also the tubular holes are very conspicuous and are frequently penetrated by the roots of the bushes above, which have doubtless acted as conductors of carbonated water.

Mr. Whitaker was informed that in Buckland Wood about a mile to the eastward the rock had been found at a depth of about 50 feet.

#### *Outliers.*

The valleys which trench the escarpment between Risborough and Wendover, and which unite above Missenden, isolate two tracts of Upper Chalk supported by the Chalk Rock.

The smaller of these, south of Great Kimble, is only three quarters of a mile long, and in it the Chalk Rock is exposed in a small excavation by the road-side above Long Down Farm.

The other, lying between the Hampden and Misbourn valleys, has a length of 3½ miles and branches into two promontories which are separated by the beautiful wooded valley below Little Hampden.

The rock caps the fine escarpment of Combe Hill and crosses the road leading from Chequers Park to Lodge Farm, just above the 700 feet contour. At Little Hampden it is exposed in an old chalk-pit about three furlongs north of the church below Hampden Leafwood. In the road by the side of Cockshoots Wood, north of Cobblershill, two beds of rock are visible, both very hard and compact, the upper being rather the harder and about two feet thick. They are about 8 or 10 feet apart, the interval being occupied by rough nodular chalk troughed by deep pockets of "clay-with-flints."

*Inliers.*

A large inlier of the Middle Chalk and Chalk Rock beds occurs in the valley of the Thames between Henley and Marlow, and the eastern part of this inlier comes within Sheet 7.

The best section however is just outside this sheet about a mile north of Henley and 400 yards from the main road, the succession being as follows:—

	FEET.
White chalk with three layers of flint nodules in the lower part; the higher part is inaccessible	15
Rather hard chalk arranged in a series of nodular layers with softer material between, a few flints scattered throughout	9
Dull white chalk consisting of hard lumps in a softer matrix. <i>Micraster</i> common; a layer of flint nodules at the base	about 10
Hard yellowish crystalline chalk with green-coated nodules, but no fossils, passing down into the next	about 4
Hard white chalk, with a layer of marly chalk about 5 feet down	about 7

There are good sections in the valley of the Thames between Henley and Marlow. In a chalk-pit above Greenland Lodge, the rock is about four feet thick and is overlain by rubbly chalk; but being at a great height above the bottom of the pit it cannot be got at: the chalk below is without flints, with the exception of two seams, not a quarter of an inch thick, that fill highly inclined fissures proceeding from a small fault, and which have clearly been deposited in those fissures from a siliceous solution flowing through them.

The outcrop of the rock runs some way up the valley north of Hambledon and may be seen by the roadside on the western flank of Pheasants Hill.

Near Medmenham, in a pit, by the side of the high road a third of a mile west of the church, there is a very good section, showing:—

- Chalk with a few flints and a layer of flints at the base; about 12 feet.
- Chalk-rock, much and evenly jointed; about 4 feet.
- Chalk without flints, with a thin layer of marl; about 10 feet.

The rock is well marked by its cream-coloured tint, contrasting with the white of the chalk both above and below; it is sharply divided from the former, but not from the latter, which is hard towards the top and passes into the rock.

Chesham is the centre of another inlier and the Chalk Rock is exposed for some distance along the valleys which trench the high ground west and north-west of the town. It is visible on three of the roads which lead out of Chesham, in the cutting at White Hill, in that up the hill to the north-west, and in that to the south-west just above Lower Germans. Thence the outcrop runs down the valley of the Chess for some distance and can be seen close by Elliotts Mill, rather more than two miles to the south-east of the town.

*Valley of the Bulbourne.*

The outcrops along this valley are continuous with those of the main escarpment to the north (in sheet 46 S.W.) but have been left till now as they are the most easterly known in our district.

Mr. Whitaker formerly saw the rock in a pit on the southern side of the railway a little east of Boxmoor station, and describes it as a little over 18 inches thick, the uppermost three inches being almost wholly made up of the phosphatic nodules; this is doubtless the lowermost bed and Mr. Whitaker states that it was overlain by rubbly reconstructed chalk (partly of pieces of the rock itself), which is probably only a part of the nodular *Micraster* Beds weathered in place.

DR. J. EVANS was the first to notice the presence of the Chalk Rock at Boxmoor, before the wide range thereof was known, or the name given.

It occurs again in the railway-cutting north-west of Apsley and it has been found about 50 feet below the surface of the ground about a quarter of a mile N.N.E. of Nash Mill.

*Fossils.*

	Thickthorn Hill, Bedlow.	Wycombe.	Elaborough.	Boxmoor.
<i>Spongida.</i>				
<i>Guettardia stellata</i> , Mich. -	x			
<i>Plocoscyphia convoluta</i> , T. Smith -	-	x		
<i>Ventriculites aleyonoides</i> , Mant. -	-	-	x	
„ <i>decurrens</i> , T. Smith -	x			
„ <i>impressus</i> , T. Smith -	-	x	x	?
<i>Actinozoa.</i>				
<i>Caryophyllia</i> (cast of) -	-	x		
<i>Paramillia centralis</i> , Mant. -	x	x	-	x
<i>Annelida.</i>				
<i>Serpula plexus</i> , Sby. -	x	-	-	?
<i>Echinodermata.</i>				
<i>Cidaris</i> (plate) -	-	x	-	x
<i>Holaster planus</i> , Mant. -	-	x	x	
<i>Micraster breviporus</i> , Ag. -	?	x	x	x
„ <i>cor-testudinarius</i> , Goldf. -	-	x		
<i>Polyzoon</i> -	-	-	-	x
<i>Brachiopoda.</i>				
<i>Rhynchonella</i> Cuvieri ?, D'Orb. (or reedensis) -	x	x	-	x
<i>Terebratula buplicata</i> , Sby. -	x	-	x	x
„ <i>carnea</i> , Sby. -	-	-	-	x
„ <i>semiglobosa</i> , Sby. -	x	x	x	x
<i>Lamellibranchiata.</i>				
<i>Inoceramus</i> Cuvieri, Sby. -	-	-	x	
<i>Inoceramus</i> (small) -	x	x	-	x
<i>Lima spinosa</i> , Sby. -	x	x	x	x
<i>Ostrea normaniana</i> , D'Orb. -	x	x	-	x
<i>Spondylus latus</i> , Sby. -	x	-	-	x
<i>Arca</i> -	x			
<i>Cardita tenuicosta</i> ?, Sby. -	x	-	-	?
<i>Cypricardia trapezoidalis</i> , Rein. -	x	-	x	
<i>Nucula</i> (cast) -	x			
<i>Gasteropoda.</i>				
<i>Avellana</i> (cast) -	x			
<i>Cerithium</i> -	x			
<i>Pleurotomaria perspectiva</i> , Mant. -	x	-	x	
<i>Trochus</i> (like cirrus) -	x	x		
<i>Turboidea</i> , sp. -	x			



	Thickthorn Hill, Bledlow.	Wycombe.	Elaborough.	Bornmoor.
<i>Cephalopoda.</i>				
<i>Ammonites prosperianus</i> , <i>D' Orb.</i> -	-	-	x	x
„ <i>bravaisianus</i> , <i>D' Orb.</i> -	-	-	x	
<i>Baculites</i> -	-	-	x	x
<i>Nautilus lævigatus</i> , <i>Sby.</i> -	-	-	x	x
<i>Scaphites æqualis</i> ?, <i>Sby.</i> -	-	-	x	x
<i>Turrilites</i> (or <i>Helicoceras</i> ) -	-	-		x

## CHAPTER 6. CRETACEOUS BEDS (CHALK).

### UPPER CHALK.

#### *General Description.*

Above the second layer of Chalk Rock there is a marked difference in the character of the Chalk; it is very white, soft, and homogeneous, weathering into thin irregular platy fragments, which strongly contrast with the dull-white nodular or lumpy chalk beneath. Within 18 inches of the Chalk Rock there is generally a thin continuous seam of flint, and sometimes there are two such seams or floors. Above them layers of flint nodules are frequent, some of these flints being very large.

Of this flinty chalk only a very small thickness is found at and near the escarpment, but as the beds sink gradually south-eastward, a greater thickness of it comes in along the sides of the valleys between the horizon of the Chalk Rock and the level of the Clay with flints, which caps the intervening ridges. In the lower beds *Micraster cortestudinarium* and *Ananchytes ovatus* are not uncommon, but fossils of any kind are rare in the overlying chalk.

About 80 or 100 feet above the Chalk Rock there is a band or zone in which nearly all the flints contain sponge-remains. The sponges seem to have been generally branching, but are sometimes cup-shaped; sometimes the silicified reticulate skeleton remains loose or but slightly attached in the centre of the flint nodule; in other cases it has decomposed and is enveloped or replaced by reddish or mauve chalcedony, the chalcedonic portion being sharply defined and limited to the area originally occupied by the sponge. Specimens of the branching skeletons sent to DR. HINDE were identified by him as *Doryderma ramosum*.

The mass of chalk with flints, characterised by the presence of *Micraster cortestudinarium* and *M. coranguinum*, and by the absence or the great rarity of *Belemnitellæ*, appears to be between 250 and 280 feet thick, and it is this part of the Chalk which directly underlies the Tertiary beds of the greater part of the London Basin. The zone of *Marsupites*, which is characterised by the presence of these Echinoderms and of *Belemnitella quadrata*, as well as by the absence or the scarcity of flints, has only yet been observed at one locality in the western part of the London Basin, namely at Taplow.

#### *Description of Sections.*

##### *Main Escarpment.*

The only sections on the escarpment are (1) a pit by the roadside on Rixborough Hill, about a quarter of a mile S.S.E. of the white cross. This exposes 12 or 15 feet of soft white chalk, with a thin seam of tabular flint

about two feet from the floor, and four layers of flint nodules in the chalk above. *Anachytes ovatus* was the only fossil found : (2) an exposure by the road-cutting near Parslows, and  $1\frac{1}{2}$  miles south-east of Princes Risborough, showing soft white chalk with layers of black flints.

Neither Mr. Whitaker nor I have had an opportunity of visiting the occasional exposures of the Chalk in the remainder of the district, but the fossil-collector, Mr. RHODES, was sent to collect from the neighbourhood of Maidenhead, Watford, and Rickmansworth, with instructions to observe the nature of the Chalk and the relative abundance of the fossils in the pits from which he collected. The following remarks are therefore drawn up from his notes and from the lists of fossils which he collected (see pp. 79-81).

#### Marlow District.

In the pit by Marlow Waterworks, north-west of the town, the lower part of the zone of *Micraster cortestudinarium* appears to be exposed. Mr. RHODES describes the chalk as greyish white, containing layers of flint nodules and of tabular flint, the total depth as 60 feet, the lower 20 feet, which only was accessible, being lumpy and irregularly bedded; a large *Inoceramus* and *Echinocorys vulgaris* are the most abundant fossils, but *Micraster breviporus* and *M. cortestudinarium* are common.

#### Berkshire. Twyford and Maidenhead District.

Chalk has been quarried in many places over this tract, and Mr. RHODES collected from such pits as were still in use, the result being to show that two pits near Bisham contain flints of a peculiar character, but that elsewhere the chalk exposed holds flints of ordinary type and contains a similar set of fossils.

The two quarries above mentioned are at Cookham Dean and by the road south of Bisham. The former is large, with a face about 70 feet high; the chalk is evenly bedded, and contains many layers of flint nodules, almost all of which include remains of sponges, chiefly *Doryderma ramosum*. There are also some layers of tabular flint; *Micraster* and *Echinocorys vulgaris* are abundant, and the horizon of this chalk is probably intermediate between that of Marlow and that of the following pits. The Bisham pit is a small exposure.

Near Wargrave the best section is in a large pit, south-east of the village, which shows about 60 feet of white chalk with layers of flint nodules; the rock is much jointed and fractured, and fossils are not abundant. Similar chalk is exposed in a pit one mile S.E. of Wargrave, in the railway-cutting north of St. Laurence Waltham, and in a pit by the side of the line further east.

On the high road to Maidenhead there are three quarries, one at Knowle Hill, another by Chalkpit Farm by Littlewick Green, and the third nearly a mile east of Littlewick. The first two show from 30 to 40 feet of chalk, much broken and unevenly bedded, with flint nodules, greyish-black inside, along definite layers. Fossils are not common, and are very friable, as if crushed. The third pit is in similar chalk with a face of 50 feet.

Near Pinkneys, north-west of Maidenhead, there are three pits in the same kind of Chalk; two at Pinkneys and one S.E. of Pinkneys Green.

At the northern end of Bisham Wood and at a higher horizon than the smaller pit to the northward is a large quarry, with a face of some 60 feet of chalk, traversed by layers of black flint nodules. Fossils are fairly abundant, and the most abundant is *Ostrea acutirostris*, which occurs in a layer about four feet above the base of the pit, associated with fragments of a large *Inoceramus*.

The Chalk in all the pits last described is characterised by certain fossils which are either absent or rare in the beds below. These are *Bourgueticrinus* (? ellipticus), *Cidaris perornata*, *Micraster coranguinum*, *Ostrea acutirostris*, *Pecten nitidus*, with many Bryozoa and *Serpula*. There can be little doubt that this chalk belongs to the zone of *Micraster coranguinum*, while that with the spongy flints may be referred to the zone of *M. cortestudinarium*.

Just eastward of this tract, on the Buckinghamshire side of the Thames, by the lodge to Taplow Court, is a large pit which shows a remarkable section.

Rubbly white chalk with scattered flint nodules	-	-	10 feet.
Greyish gritty chalk in blocky masses, resembling Totternhoe			
Stone, without flints	-	-	20 feet.
White chalk with greyish markings and very few flints	-	-	40 feet.

Fossils are scarce, except in the middle greyish chalk, in which *Belemnitella quadrata* and *Ostrea acutirostris* are common: the occurrence of the *Belemnitella* and the comparative scarcity of flints suggest a correlation of this chalk with the well known Margate Chalk or the zone of *Marsupites*.

The section Fig. 4 is drawn to show the probable relations of this Taplow chalk to that of Marlow, Bisham, and Cookham Dean. It is constructed on the assumption that the whole of the Cookham Dean chalk lies below that of Taplow, and that its thickness is about 250 feet.

#### Hertfordshire (and Middlesex).

The Chalk-pits in the neighbourhood of Rickmansworth and Watford were also visited by Mr. RHODES, and the following remarks have been drawn up mostly from his notes.

The section at Harefield cement works is described in chap. 13. Fossils are not abundant, except *Polysia* and *Bourgueticrinus*. This chalk probably belongs to the same horizon as that west of Maidenhead; on the opposite side of the Colne there is a smaller pit in similar chalk, and a third by Troy Farm.

Another large pit, by the canal at the northern end of Harefield Park, shows about 80 feet of chalk, the lower part of this extending to a lower horizon than the southern pit; fossils are fairly abundant in the lowest 20 feet, and include *Micraster cortestudinarium*, and though solid flints occur throughout, many are of the hollow kind containing sponge-remains. The upper 30 feet contain *Bourgueticrinus* and a few other fossils, but this part is probably in or bordering on the higher zone. This section is further referred to in chap. 19.

The next pit by the canal, about 6 furlongs due north of the last seems also to be opened at the junction of the zones of *Micraster cortestudinarium* and *M. coranguinum*, for about 40 feet above the floor there is a layer which contains *Ostrea acutirostris* and fragments of a large *Inoceramus*, similar to that occurring at Bisham Wood, near Marlow. There is another pit in similar chalk to the eastward, by Stockers Farm; many of the flints in both pits contain remains of Sponges.

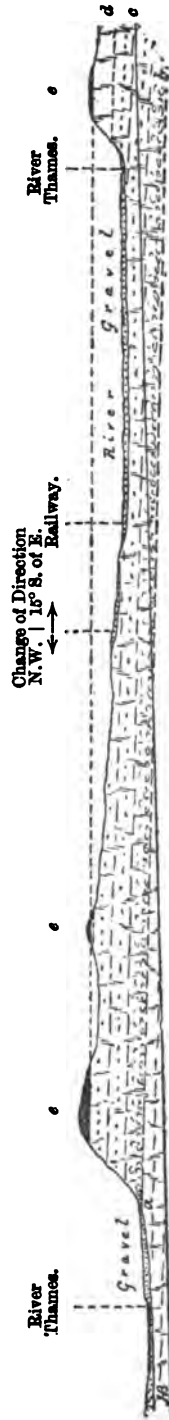
The cuttings on the railway at Rickmansworth and by Croxley Hall, eastward, are in chalk with nodules and tabular layers of flint, and did not yield many fossils; they are probably in the higher zone, and if so they must be brought in by a slight synclinal curve across the strike of the beds. The same chalk is exposed in the cutting by Sandy Lodge, two miles S.E. of Rickmansworth, and in a pit by the side of the line to Watford, two miles east of Rickmansworth.

If the character of the flints can be trusted as a guide in separating the zones in this part of the Chalk, the lower zone would appear to occur in the cutting and tunnel north-east of Watford Junction, for Mr. RHODES observed that at this locality some 90 per cent. of the flints contain decomposed sponges. From the chalk in the cutting he did not obtain any fossils except from washing the material which fills the flints, but from the spoil-heap brought up from the shaft at the southern end of the tunnel he obtained the species listed on pp. 79, 80. The same kind of flints were here associated with them.

At the large pit north of the high road between Watford and Bushey, about 60 feet of chalk is exposed, the upper part being described by Mr. Rhodes as "yellow banded chalk, pieces of which are very hard," and the lower 30 feet as "white chalk," layers of solid flint nodules occurring throughout the section. Another pit in white chalk with similar flints and fossils exists at Letchmoor Heath, on the road to Aldenham.

Similar chalk to that in the Watford cutting occurs in Berry Wood, westward of Aldenham, where Mr. J. HOPKINSON has noted "a chalk pit abound-

Figure 4. Section from Bisham to Taplow.



Horizontal scale  $1\frac{1}{4}$  inches to a mile. Vertical scale 800 feet to an inch.

x x. Ordnance Datum (or mean sea-level).

e = Reading Beds (Outliers of Cookham Dean Common and of Taplow).

Upper { d = Chalk with few flints.

Chalk { c = Chalk with many flints.

{ b. Lumpy Chalk with the Chalk Rock at the bottom.

a. Middle Chalk.

ing in the remains of sponges, surrounded by mere shells of flint, and containing "spicules," Foraminifera, and even Polyzoa, beautifully preserved."\* Later notes of this pit, which is close to the Colne, say that the Chalk is irregularly capped by Drift, and that specimens of *Globigerina haloides* were got.†

North of Aldenham there are four pits in chalk with nodular flints, and all yielding *Ostrea acutirostris* as the commonest fossil; two of these are respectively half a mile and a mile east of Mundon, one is west of Wild Farm, and one lies south-east of Colney Street. The same kind of chalk is exposed in two other small pits still further west, one a mile and a quarter south-east of London Colney, and one between Pink Farm and Rabbley.

### Fossils.

In the following list the localities in Berkshire and Buckinghamshire are shown by letters, thus:—

- |                             |  |
|-----------------------------|--|
| a. Marlow.                  | d. Pinkneys.                           |
| b. Bisham and Cookham Dean. | e. Littlewick (3 pits).                |
| c. Bisham Wood.             | f. Wargrave and St. Laurence, Waltham. |

Those in Hertfordshire and Middlesex are marked by numbers, as follows:—

1. Troy Farm and Wheyberds, on the right side of the Colne, opposite Harefield.
2. Harefield.
3. Harefield Park.
4. Rickmansworth, south of the Colne.
5. Rickmansworth, north of the Colne.
6. Watford.
7. Bushey and Letchmoor.
8. Colney Street and neighbourhood.

—	Berkshire and Buckinghamshire.					Hertfordshire and Middlesex.							
<i>Spongida.</i>													
<i>Doryderma ramosum, Mant.</i>	—	b	—	—	—	—	—	3	—	—	—	—	? 6
<i>Guettardia stellata, Mich.</i>	a	b	—	—	—	f	1	—	—	—	—	—	—
<i>Plocoscyphia convoluta, Smith.</i>	a	—	—	—	—	—	—	—	—	—	—	—	—
<i>Thamnospongia</i>	—	—	—	d	—	—	—	—	—	—	5	—	7
<i>Ventriculites impressus, Smith.</i>	a	—	—	—	—	—	—	—	—	—	—	6	—
" <i>mamillaris, Smith.</i>	a	—	—	—	—	—	—	—	—	—	—	—	—
" <i>radiatus, Mant.</i>	a	—	—	—	—	—	—	—	—	—	—	—	—
" sp.	—	b	—	—	—	f	—	—	—	—	—	—	—
<i>Echinodermata.</i>													
<i>Bourguetierinus ellipticus?, Mill.</i>	—	—	—	—	—	—	—	2	—	—	—	6	7 8
sp.	—	—	o	d	e	f	—	—	—	—	5	6	7
<i>Cidaris clavigera, Mant.</i>	—	b	—	d	e	f	—	—	—	—	5	6	7
" <i>hirudo, Sorig.</i>	—	—	—	d	e	—	—	—	—	—	—	—	—
" <i>perornata, Forbes.</i>	—	—	o	d	—	—	—	—	—	—	5	6	7
" <i>scoptrifera, Mant.</i>	—	—	—	d	—	—	—	—	—	—	5	—	—
" <i>subvesiculosa, D'Orb.</i>	—	—	—	d	—	—	—	—	—	4	5	6	7 8
<i>Cyphosoma</i>	—	b	—	—	e	—	—	—	—	—	—	—	—
<i>Diadema (spines)</i>	—	—	o	—	—	—	—	—	—	—	—	—	—
<i>Echinocoelus confusus, Breyn.</i>	—	—	—	d	—	—	1	—	—	—	—	—	7
<i>Echinocorys vulgaris, Breyn.</i>	—	—	—	—	—	—	—	—	—	—	—	—	—
(= <i>Ananchytes ovatus</i> )	a	b	o	—	e	f	1	2	3	4	5	6	7
<i>Goniaster Parkinsoni, Forbes.</i>	—	—	—	—	—	—	—	—	3	—	—	—	—
sp. (ossicles only in Herta.)	a	—	—	—	—	—	1	—	—	—	5	—	7 8
<i>Holaster</i>	—	—	—	—	—	f	—	—	—	—	—	—	—
<i>Micraster breviporus, Ag.</i>	a	—	—	—	e	—	—	—	—	—	—	—	—
" var. <i>cor-</i>	—	—	—	—	—	—	—	—	—	—	—	—	—
" <i>bovis, Forbes.</i>	a	b	—	—	—	—	—	—	—	—	—	—	—
" <i>cor-anguinum? Leske</i>	—	—	o	—	? e	f	—	? 2	—	4	5	—	7
" <i>cor-testudinarium, Goldf.</i>	a	b	—	d	—	f	1	—	3	—	5	—	7
<i>Oreaster</i>	—	—	—	—	—	—	—	—	—	—	—	6	—
<i>Pseudodiadema (spine)</i>	—	—	—	—	—	—	—	—	—	—	—	—	7

\* *Proc. Geol. Assoc.*, vol. ii. no. 2 p. 44. (1871.)

† *Proc. Geol. Assoc.*, vol. iv. no. 5 p. 284. (1875); and *Trans. Watford Nat. Hist. Soc.*, vol. i. pt. 3 p. xvi. (1876.)

	Berkshire and Buckinghamshire.					Hertfordshire and Middlesex.							
<i>Hydrosoc.</i>													
<i>Porosphaera urceolata</i> , Phil.	—	—	—	—	e	—	—	—	—	—	—	—	8
" <i>Woodwardi</i> ?, Carter	—	—	—	d	—	—	—	2	3	—	5	6	8
" sp.	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Actinosoc.</i>													
<i>Parasemilla</i> -	—	—	—	—	—	—	—	—	—	—	6	7	—
<i>Annelida.</i>													
<i>Serpula granulata</i> , Sby.	—	—	—	—	e	—	—	—	—	—	6	—	8
" <i>ilium</i> , Goldf.	—	—	—	—	e	f	—	2	—	—	6	7	8
" <i>plana</i> , Wood	—	—	c	d	e	—	—	—	—	—	—	—	—
" <i>plexus</i> , Sby.	—	—	—	—	e	—	—	—	—	—	—	—	—
" <i>proteus</i> ?, Sby.	—	—	—	—	—	—	—	—	—	—	6	—	—
" <i>turbinella</i> , Sby.	—	—	—	—	e	—	—	—	—	—	—	—	—
" sp.	—	b	—	d	—	—	—	—	—	—	—	—	—
<i>Terebella lewesiensis</i> , Davis	—	—	—	d	—	—	—	—	—	—	—	—	—
<i>Polyosoc.</i>													
<i>Actinopora diademoides</i> , D'Orb.	—	—	—	—	—	—	—	2	—	—	—	—	—
<i>Alecto</i>	—	—	—	—	—	—	—	2	—	—	—	—	—
<i>Bicavea dilatata</i> , D'Orb.	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Collepore</i>	—	—	—	—	—	—	—	2	—	—	—	—	—
<i>Orthis subgracilis</i> , D'Orb.	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Defrancia</i>	—	—	—	—	—	—	—	—	—	—	—	—	7
<i>Diastopora</i>	—	—	b	—	e	—	—	—	4	—	6	—	—
<i>Discopora</i>	—	—	—	—	f	—	—	—	—	—	—	—	—
<i>Domopora clavata</i>	—	—	—	—	—	—	—	—	—	—	6	—	—
" ?	—	—	—	—	—	—	—	2	—	—	—	—	—
<i>Entalophora clavata</i> ?, D'Orb.	—	—	—	—	—	—	—	—	—	—	6	—	—
" <i>obliqua</i> , D'Orb.	—	—	—	—	—	—	—	1	—	—	6	—	—
" <i>rariopora</i> , D'Orb.	—	—	—	—	—	—	—	—	—	—	6	—	—
" sp.	—	—	—	d	—	—	—	—	—	—	—	—	7
<i>Eschara</i>	—	—	—	—	—	—	—	—	—	—	6	—	—
<i>Escharina</i>	—	—	—	—	e	—	—	2	—	—	5	—	—
<i>Frustrularia granulosa</i> , D'Orb.	—	—	—	—	e	—	—	—	—	—	6	—	—
<i>Idmones</i>	—	—	—	—	e	—	—	—	—	—	—	—	—
<i>Membranipora normaniana</i> , D'Orb.	—	—	—	—	f	—	—	—	—	—	—	—	—
" sp.	—	—	—	d	—	—	—	—	—	—	6	—	—
<i>Proboscina angustata</i> , D'Orb.	a	—	—	—	—	—	—	—	—	—	—	—	—
" <i>ramosa</i> ?, Mich.	a	—	—	—	e	—	—	—	—	—	—	—	—
" sp.	—	—	—	—	e	f	—	—	—	—	—	—	—
<i>Semieschara arborea</i> , D'Orb.	—	—	—	—	—	f	—	—	—	—	—	—	—
<i>Stomatopora rames</i> , Blaine.	—	—	—	—	—	—	—	1	—	—	—	—	—
<i>Truncatula alternata</i> , D'Orb.	—	—	—	—	—	—	—	—	—	—	6	—	8
<i>Vincularia</i>	—	—	—	—	—	—	—	—	—	—	6	—	8
<i>Brachiopoda.</i>													
<i>Argiope megatrema</i> , Ag.	—	—	—	—	—	—	—	—	—	—	6	—	—
<i>Crania ignabergensis</i> , Retz.	—	—	—	—	f	—	—	—	—	—	6	7	8
" <i>parisiensis</i> , Duf.	—	b	—	e	—	—	—	1	2	—	—	—	—
<i>Kingena lima</i> , Duf.	—	—	—	e	f	—	—	—	—	—	6	—	—
<i>Rhynchonella Cuvieri</i> ?, D'Orb.	—	—	c	d	—	—	—	—	—	—	—	—	—
" <i>plicatilis</i> ?, Sby.	—	—	—	—	—	—	—	—	—	—	—	—	—
" sp.	a	b	—	e	f	—	—	2	—	4	5	6	8
<i>Terebratulina semiglobosa</i> , Sby.	a	b	c	d	e	f	—	—	3	4	—	6	7
<i>Terebratulina striata</i> , Wall.	—	—	—	d	—	—	—	1	—	—	5	6	7
<i>Thecidium Wetherelli</i> , Mor.	—	—	—	—	—	—	—	2	—	—	—	—	—
<i>Lamellibranchiata.</i>													
<i>Inoceramus Brongniarti</i> ?, Sby.	—	b	—	—	—	—	—	—	—	4	—	—	—
" <i>Cuvieri</i> ?, Sby.	a	b	—	d	—	—	—	—	—	3	—	—	—
" <i>involutus</i> , Sby.	—	—	—	—	—	—	—	—	—	—	—	—	—
" <i>Lamarckii</i> ?, Park.	—	—	c	d	e	f	—	1	2	—	—	—	—
" sp.	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Lima spinosa</i> , Sby.	a	—	—	d	e	—	—	—	—	—	—	7	8
" sp.	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Ostrea acutirostris</i> , Nils. (species queried in Herts. list)	—	—	c	—	e	—	—	—	—	4	—	—	—
" <i>normaniana</i> , D'Orb.	—	—	—	—	—	—	—	1	—	—	—	—	—
" sp.	a	—	—	d	e	f	—	—	—	4	—	—	—
<i>Pecten nitidus</i> , Mont.	—	—	—	d	e?	f	—	—	2	—	5	—	—
" <i>quinquecostatus</i> , Sby.	—	—	—	—	—	f	—	—	—	—	—	7	8
" sp.	—	—	—	—	—	—	—	1	—	—	—	6	—
<i>Spondylus</i>	—	—	c	—	—	f	—	—	2	—	—	—	7

—	Berkshire and Buckinghamshire.	Hertfordshire and Middlesex.
<i>Cephalopoda.</i>		
<i>Belemnites quadrata, Depr.</i> .	— — — — e	
<i>Scaphites</i> .	a	
<i>Fish.</i>		
<i>Cimolichthys lowesiensis, Leidy</i>	— — — — d e f	
<i>Fish remains</i> .	— — — — d e f	— 2 — — — — 7 8

## SOUTHERN OUTCROP (by W. W.).

With the Upper Chalk of the southern side of the London Basin we have little to do here, only such of it as directly borders the Thames below London being within our district.

Through Surrey, from Leatherhead to Croydon the Chalk rises markedly southward, from beneath the low-lying Tertiary beds, the dip, especially to the west, being at a higher angle than on the northern outcrop, in Buckinghamshire etc.

From Croydon eastward to the Valley of the Cray it is much the same, but that the Tertiary beds have a far more marked escarpment, with a higher base of Chalk.

The sections over this tract of Chalk, which is much narrower than that to the north, on account of the higher dip, fall to be described in Memoirs on Sheets 6 and 8.

Most of the sections along the Valley of the Thames will be described in treating of the Tertiary beds, or of the Drift.

*Kent.*

Along the southern side of the Thames the Chalk seems to rise up in a set of inliers, from the eastern part of London to Abbey Wood.

*Chislehurst.*—The sections of the small inlier of Camden Park, about a mile long from N.W. to S.E., and nowhere a sixth of a mile broad, will be more conveniently noticed further on (see pp. 115–117). Some of these chalk-pits seem to have been worked in very distant times, and they have yielded many fossils, mostly recorded as from Bromley.

*Deptford.*—Under the marshes north-west of this place the Chalk is brought up in the form of a very flat dome, which has been levelled down by denudation. The Chalk is everywhere covered by alluvium or by gravel, but its presence next below those deposits has been shown by borings.

*Greenwich, &c.*—The strip of Chalk on the southern side of the fault from St. John's Road Station to Woolwich, bounded on the north by that fault, would seem to be an inlier; the sections are described further on (pp. 114, 154, &c.).

*Plumstead.*—Eastward of this village a small outcrop, again bounded on the north by a fault, runs southwards, for about two thirds of a mile, along the bottom of the valley towards East Wickham, but is nowhere more than quarter of a mile broad. Chalk has been worked here.

*Abbey Wood.*—About two-thirds of a mile south-east of the railway-station, there is a very small outcrop in the wood.



Bordering the river or the marshes from Stone to Gravesend there are many large pits.

In a chalk-pit on the Watling Street a little more than a mile S.S.E. of Stone, there are, along the planes of bedding, some layers of brown sandy clay, sometimes eight inches thick, in parts rather finely bedded. These layers are of course owing to the percolation of water with earth suspended in it. Fig. 5 has been reduced from a drawing of this section made by PROF. HUGHES, which shows a communication with the surface, the height being about 20 feet and the length about 60.

Figure 5. Section in a Chalk Pit about a mile S.S.E. of Stone.



"Chalk, with finely bedded loam and clay, mostly in the direction of and often passing into layers of flints, and sometimes connected with cracks from the surface."

The REV. T. WILTSHIRE has a large collection of pebbles of old rocks from the Chalk of the neighbourhood of Gravesend, and it is to be hoped that these may be examined petrologically. The boulder of granite found in the chalk of Purley, southward of Croydon and outside our district, has been described.\*

*Cliffe.*—An outcrop of the Upper Chalk occurs in the somewhat desolate Hundred of Hoo, and is bordered on the south and east by the Thanet Beds, from below which the Chalk rises up, and on the north and west by the marshes of the Thames, which river has cut off the Chalk rather abruptly on the north-west. This outcrop is about two miles from east to west, and about a mile from north to south, so that its area is about two square miles, over which the rock is bare, except for the thin soil.

It is not unlikely that this is an inlier, the Chalk forming a very flat dome, surrounded on all sides by the Thanet Beds, but with its northern and western extension hidden under the marshes; on the other hand however it may join on (under the Thames) to the Essex outcrop on the west, and by that to the Kentish tract on the south.

In the large pit at the edge of the marsh about three quarters of a mile west of Cliffe the even bedding of the Chalk is shown by the layers of flints. At the northern face there is a very slight easterly dip, but elsewhere the beds are flat. Towards the top there is a continuous layer of flint, which is perhaps more marked in a smaller section in the cliff-face a little to the south-west.

An analysis of the Cliffe chalk is given further on.

\* GODWIN-AUSTEN, *Quart. Journ. Geol. Soc.*, vol. xiv. p. 252 (1858).

*Essex.*

Owing to a local rise of the beds, which has resulted in their forming a flat arch across the Valley of the Thames, the Chalk crops out from Purfleet eastward to beyond Little Thurrock. It is much worked, many of the pits showing the junction with the overlying Thanet Sand (see pp. 117, 118) and some that with the Valley Drift (see chap. 22).

The late MR. MEESON told me that he had bored from the bottom of the large chalk-pit at Grays Thurrock, where the chalk has been worked to a depth of 90 feet, with the following result :—

White chalk with flints; 20 feet.

White chalk without flints; about 80 feet.

Green sand [? pipe of Thanet Sand] full of water; 2 feet.

Grey chalk; 6 feet or more.

MR. MEESON also told me that at the Malting close to the river a bore had been made to the depth of 680 feet, about 25 feet of this being through "sand, gravel, and river deposit," then about 100 feet through white chalk, the rest being in "grey chalk," which was not bored through. The greyness is probably owing to wetness.

There would seem to be some mistake as to the depth, for at Crossness (no great way off) as well as in all the other deep borings near London, the Chalk, when pierced from top to bottom, does not reach the thickness above assigned to it in a boring that begins some way from the top, and is said not to get to the bottom of the formation. Nor have we any reason to expect a great easterly thickening, as at Chatham, many miles further in that direction, the total thickness is only a little over 680 feet.

At East Tilbury again there is a short and narrow outcrop between the Thanet Sand and the alluvium of the Thames.

*Fossils.*

The following list has been compiled by MR. JUKES-BROWNE, from the Catalogue of the collection in the Jermyn Street Museum, from DR. LAVIS' paper (*Proc. Geol. Assoc.*, vol. iv. no. 9, pp. 528, 530), from a list of the late Mr. Wetherell's collection (taken by me), supplemented by references from the monographs of the Palæontographical Society, and from specimens in the collections of Mr. Jukes-Browne and of myself.

The localities are marked as follows :—

1 = Lewisham (Loam Pit Hill).

2 = Charlton and Woolwich.

3 = Gravesend and Northfleet.

4 = Grays and Purfleet (Essex).

*Spongida.*

<i>Elasmostoma scitulum</i> , <i>Hinde</i>	-	-	-	-	2	
<i>Pharetrosporgia Strahani</i> , <i>Sollas</i>	-	-	-	-	2	
<i>Ventriculites convolutus</i> , <i>Hinde</i>	-	-	-	-	-	3

*Hydrozoa.*

<i>Porosphaera globularis</i> , <i>Phil.</i>	-	-	-	-	-	3
" <i>urceolata</i> , <i>Phil.</i>	-	-	-	-	-	4

*Actinozoa.*

<i>Caryophyllia cylindræa</i> , <i>Reuss</i> (Cyathina)	-	-	-	2	3	4
<i>Diblasus gravenensis</i> , <i>Lonsd.</i>	-	-	-	-	3	
<i>Onchotrochus serpentinus</i> , <i>Dunc.</i>	-	-	-	2		
<i>Parasmilia centralis</i> , <i>Mant.</i>	-	-	-	-	3	
" <i>monile</i> , <i>Dunc.</i>	-	-	-	-	3	
" <i>serpentina</i> , <i>Edw. &amp; Haime</i>	-	-	-	-	3	

*Echinodermata.*

<i>Antedon paradoxa</i> , Goldf.	-	-	-	-	-	3	
<i>Bourgueticrinus ellipticus</i> , Mill.	-	-	-	-	1	2	3
<i>Cardiaster pillula</i> , Lam.	-	-	-	-	-	2	
<i>Cidaris clavigera</i> , König.	-	-	-	-	-	2	3
" <i>hirudo</i> ?, Sorig.	-	-	-	-	-	-	3
" <i>perornata</i> , Forbes	-	-	-	-	-	-	3
" <i>sceptrifera</i> , Mant.	-	-	-	-	-	-	3
" <i>subvesiculosa</i> , D'Orb.	-	-	-	-	-	2	3
<i>Cyphosoma corollare</i> , Klein	-	-	-	-	-	2	3
" <i>granulosum</i> , Goldf.	-	-	-	-	-	-	3
" <i>Königii</i> , Mant.	-	-	-	-	-	2	3
" <i>radiatum</i> , Sorig.	-	-	-	-	-	-	3
" <i>spatuliferum</i> , Forbes	-	-	-	-	-	-	3
" <i>Wetherelli</i> , Forbes	-	-	-	-	-	-	3
<i>Echinoconus castanea</i> ?, Brongn.	-	-	-	-	-	-	3
" <i>conicus</i> , Breyn.	-	-	-	-	1	2	3
" <i>subrotundus</i> , Mant.	-	-	-	-	-	-	3
" <i>globulus</i> , Desor.	-	-	-	-	-	2	3
<i>Echinocorys vulgaris</i> , Breyn. (= <i>Ananchytes ovatus</i> )	-	-	-	-	1	2	3
<i>Goniaster Coombii</i> , Forbes	-	-	-	-	-	2	
" <i>lunatus</i> , Woodw.	-	-	-	-	-	-	3
" <i>Parkinsoni</i> , Forbes	-	-	-	-	1	2	3
" <i>rugatus</i> ?, Forbes	-	-	-	-	-	-	3
" <i>uncatus</i> , Forbes	-	-	-	-	-	-	3
" <i>new sp.</i>	-	-	-	-	-	2	
<i>Holaster planus</i> , Mant.	-	-	-	-	-	-	3
<i>Micraster coranguinum</i> , Leske	-	-	-	-	1	2	3
<i>Ophiura serrata</i> , Röm.	-	-	-	-	-	-	3
<i>Oreaster Boysii</i> , Forbes	-	-	-	-	-	2	
" <i>bulbiferus</i> , Forbes	-	-	-	-	-	-	3

*Annelida.*

<i>Serpula ilium</i> , Goldf.	-	-	-	-	-	-	3
" <i>plexus</i> , Sby.	-	-	-	-	-	-	3
" <i>turbinella</i> , Sby.	-	-	-	-	-	-	3
" <i>sp.</i>	-	-	-	-	-	-	4

*Crustacea.*

<i>Enoploclytia brevimana</i> , McCoy	-	-	-	-	-	-	3
" <i>Leachii</i> , Mant.	-	-	-	-	-	2	3
<i>Pollicipes glaber</i> , Röm.	-	-	-	-	-	-	3
<i>Scalpellum maximum</i> , Sby.	-	-	-	-	-	-	3

*Polyzoa.*

<i>Crisina triangularis</i> , D'Orb.	-	-	-	-	-	-	4
<i>Homæosolen ramulosus</i> , Lonsd.	-	-	-	-	-	-	

*Brachiopoda.*

<i>Cistella</i> ( <i>Argiope</i> ) <i>Bronnii</i> , De Hag	-	-	-	-	-	-	3
<i>Crania ignabergensis</i> , Retz.	-	-	-	-	1?	2	3
" <i>parisiensis</i> , DeFr.	-	-	-	-	-	-	3
<i>Kingena lima</i> , DeFr.	-	-	-	-	-	-	3
<i>Magas pumila</i> , Sby.	-	-	-	-	-	-	3
<i>Rhynchonella mantelliana</i> ?, Sby. (? <i>Reedensis</i> )	-	-	-	-	-	-	3
" <i>plicatilis</i> , Sby.	-	-	-	-	-	-	3
" <i>var. ostoplicata</i> , Sby.	-	-	-	-	1?	2	
<i>Terebratula carnea</i> , Sby.	-	-	-	-	1	2	3
" <i>semiglobosa</i> , Sby.	-	-	-	-	1	2	3
<i>Terebratulina striata</i> , Wahl.	-	-	-	-	-	-	3
<i>Thecidium Wetherellii</i> , Mor.	-	-	-	-	-	2	3

*Lamellibranchiata.*

<i>Inoceramus cordiformis</i> , Sby.	-	-	-	-	-	3	
„ <i>digitatus</i> , Sby.	-	-	-	-	-	3	
„ <i>sp.</i>	-	-	-	-	1	2	4
<i>Lima Hoperi</i> , Sby.	-	-	-	-	-	2	4
„ <i>sp.</i> (not elongata)	-	-	-	-	-	-	3
<i>Modiola quadrata</i> , Sby.	-	-	-	-	-	-	3
<i>Ostrea acutirostris</i> , Nills.	-	-	-	-	-	-	3
„ <i>flabelliformis</i> , Nills.	-	-	-	-	-	-	3
„ <i>frons</i> , Park.	-	-	-	-	-	-	3
„ <i>normaniana</i> , D' Orb.	-	-	-	-	-	-	3
„ <i>semiplana</i> , Mant.	-	-	-	-	-	-	3
„ <i>vesicularis</i> , Lam.	-	-	-	-	-	2	3
<i>Pecten nitidus</i> , Mant.	-	-	-	-	1?	2	3
„ <i>quinquecostatus</i> , Sby.	-	-	-	-	-	2	3
<i>Radiolites Mortoni</i> , Mant.	-	-	-	-	-	-	3
<i>Spondylus hystrix</i> ?, Goldf.	-	-	-	-	-	-	3
„ <i>latus</i> , Sby.	-	-	-	-	-	-	3
„ <i>spinosus</i> , Sby.	-	-	-	-	1	2	3

*Cephalopoda.*

<i>Ammonites leptophyllus</i> , Sharpe (= <i>lewesiensis</i> , Sby. not Mant.)	-	-	-	-	-	-	3
<i>Belemnites lanceolata</i> , Schloth.	-	-	-	-	1?	2?	3
„ <i>Merceyi</i> , Mayer	-	-	-	-	-	-	3
„ <i>vera</i> ?, Mill	-	-	-	-	-	-	3

*Pisces.*

<i>Cimolichthys lewesiensis</i> , Leidy	-	-	-	-	-	-	3
<i>Corax heterodon</i> , Reuss	-	-	-	-	-	-	3
<i>Enchodus lewesiensis</i> , Mant. (= <i>haloeyon</i> , Ag.)	-	-	-	-	-	2	3
<i>Hoplopteryx lewesiensis</i> , Mant. (= <i>Beryx ornatus</i> )	-	-	-	-	-	-	3
<i>Notidanus microdon</i> , Ag.	-	-	-	-	-	-	3
<i>Otodus appendiculatus</i> , Ag.	-	-	-	-	1	2	3
<i>Oxyrhina Mantelli</i> , Ag.	-	-	-	-	-	-	3
<i>Ptychodus decurrens</i> , Ag.	-	-	-	-	1?	2?	3
„ <i>polygyrus</i> , Ag.	-	-	-	-	-	-	3

## CHAPTER 7. LOWER LONDON TERTIARIES.

### GENERAL REMARKS.

The varied assortment of clays, sands, and pebble-beds that come between the Chalk and the London Clay is comparatively thin, and represents probably a small amount of geological time, as compared with the thicker and more homogeneous masses of the underlying and of the overlying formations; but yet there is more to be said about it than about both of these. Though the outcrop is generally narrow, yet sections are fairly numerous, and over the one wide outcrop, south-east of London, they are not only plentiful, but many of them are large also. Moreover these sections show such changeful beds, pointing often to changes in the character of the deposit, that in geological interest this Series is probably second to none in our district. The fossils too have a special interest, from being mostly (in our district) of an estuarine or freshwater kind, that is of a kind comparatively rare in the series of stratified rocks, in which marine fossils are by far the more plentiful. Those deposits which point to the existence of land-surfaces at no great distance seem to have an importance beyond what is given by mere thickness or extent.

Placed between the 450 feet of the London Clay and the 650 feet of the Chalk, it is only at parts of their southern outcrop that the Lower London Tertiaries reach a thickness of 100 feet, and, as far as we know, it is only eastward of London and of Croydon that this is exceeded, and then not very much. Looking to the long array of well-sections in the Appendix, we find only nine in Kent in which the total thickness of the Series reaches 120 feet (at Bexley, Bostal Heath, Bromley, and Eltham), two others, at Greenwich, being doubtful, and in one only does this thickness just reach 150 feet (Bromley). In Essex six sections (at Brentwood, Corringham, Prittlewell, Southend, Thames Haven, and Vange) reach the first standard, one of them (Thames Haven) just reaching the second, whilst at two (Prittlewell and Southend) the thickness is more, in the last exceeding 180 feet, just at the eastern edge of our district.

The Lower London Tertiaries are an example therefore of the fact that geologic interest does not always rest with thick deposits, with broad outcrops, or with lengthened periods; but may be largely shared by formations of a more or less local and transitory character: indeed it is the local and exceptional conditions shown in this Series that are its chief claim to consideration, rather than those that occur over a far larger area; for the Thanet Beds, with their marine fossils (in East Kent), the estuarine Woolwich Beds, and the irregular but often fossiliferous Blackheath and Oldhaven Beds (chiefly pebbles in the west, but sand in the east) are of higher interest than the much more general but almost unfossiliferous Reading Beds.

That these beds have always been of interest to geologists will be seen by the following account of their literature, which is confined however to our special district, as much as possible, and in which reference is made only to books treating of nomenclature and classification, not to such as give simply stratigraphical details.

#### HISTORY AND LITERATURE.

The earliest detailed notice of this varying set of beds in the London District seems to be by J. PARKINSON,\* who, after describing the Blue [or London] Clay, goes on to say "It is almost impossible to speak with precision of the subjacent strata . . . . between the clay and the chalk, since very considerable variations occur as to their thickness, and indeed as to the form in which their constituent parts are disposed; and since there exist but few sections, at least in the neighbourhood of the metropolis, which present a view of the strata composing this formation," and he then refers to sections at Charlton, Plumstead, etc.; but he seems to have mistaken some of the Woolwich shelly clay for London Clay, and not to have included the overlying pebble-beds (except in the case of the shelly conglomerate near Bromley), probably taking them to belong to the "sand and gravel" above the London Clay.

In a paper more especially devoted to the Tertiary beds of the Isle of Wight, T. WEBSTER referred also to the London Basin and described various sections in our district,† under the heading "Sand and Plastic Clay," remarking "that considerable difficulties appear to me to exist in assigning a place to the Woolwich beds. The actual lowness of their level, *appearing* to dip under the London clay, and their situation near the chalk without the intervention of that bed, at first seem to determine their geognostic position. Whilst the circumstances of their not being seen in any part covered by the London clay, nor having been actually identified with any strata which have been found in sinking through it with certainty, leave the question still undetermined; and the agreement of the fossils . . . . with those of the upper marine formation in the Isle of Wight . . . . is sufficiently striking to suggest the idea of a similarity in the circumstances of their production." The pebble-bed of Blackheath, etc. he classed under "Alluvium," a term which then included much, being more or less equivalent to our term "Drift."

Two years later WEBSTER again referred to this Series, as above, and also varied the name by transposing the terms; but he did not adopt the simple name of Plastic Clay.‡

In 1817 PROF. BUCKLAND§ adopted the name Plastic Clay, and described sections at Reading and near London, the latter

\* *Trans. Geol. Soc.*, vol. i. pp. 341-344. (1811.)

† *Trans. Geol. Soc.*, vol. ii. pp. 195-197, 221, 222, 235, 236. (1814.) The term "Plastic Clay" was simply adopted from the French, *argile plastique*.

‡ Pp. 210, 236 of "A Description of the Principle Picturesque Beauties . . . . of the Isle of Wight" by Sir H. Englefield. 4<sup>to</sup>. Lond. 1816.

§ *Trans. Geol. Soc.*, vol. iv. pp. 277-294, plate 13.

in more detail than had been done before; but the Blackheath pebbles were still regarded as "alluvial," though those of Sundridge were classed with this Series. The extent of the Woolwich shell-beds is here first traced out.

The author's general conclusion may be given in his own words:—"Viewing it on the great scale then we may consider this formation . . . as composed of an indefinite number of sand, clay, and pebble beds, irregularly alternating . . . . Again, the occurrence of organic remains in the different beds of this formation, is like the alternation of the strata composing it, exceedingly irregular."

The next year W. PHILLIPS,\* whilst repeating the matter of previous writers, noticed an objection to the then accepted name, as follows:—"By the term Plastic clay, we might be, at first sight, induced to suppose it to consist only or chiefly of clay, which does not appear to be the fact."

SIR C. LYELL† adopted the compound name "Plastic clay and sand," merely inverting the terms as used by Webster.

In his "Observations on the Strata near Woolwich,"‡ my first teacher in Geology, PROF. MORRIS, noticed (? for the first time) the occurrence of "evident fluviatile shells" in the clay shell-beds at that place.

In 1837 PROF. MORRIS,§ objecting apparently to the term Plastic Clay, classed these beds with the London Clay, dividing them into three, (1) "those containing the Reading oyster," or the clayey greensand next overlying the Chalk; (2) "the Woolwich and Upnor strata," including presumably all the Thanet Sand; and (3) the Bognor or lower arenaceous beds of the London clay," including some of the clayey Thanet Beds of East Kent, and apparently the mottled plastic clays, etc. It seems however that the author makes these divisions, not as pointing to successive deposits, but as different conditions of one Series.

Up to this the subject had been hampered, though not as regards our district, by the inclusion with the Plastic Clay, in the Isle of Wight and in other parts of the Hampshire Basin, of the true London Clay and of part of the Bagshot Series, the Barton Clay having sometimes been taken for London Clay. In 1846 however the geologist who finally cleared up the question of the classification of our Lower Tertiary formations, and who has done more indeed for English Tertiary Geology than anyone else (one may almost say than all others together) published the first of his long series of papers.|| Though PROF. PRESTWICH therein treated especially of the Isle of Wight, yet reference is made to our district; for, on p. 233, he remarks, "I purpose to restrict the

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\* A Selection of Facts from the best Authorities, arranged so as to form an Outline of the Geology of England and Wales. 8°. Lond. 1818, p. 28. This work is the base on which the well-known book by Phillips and Conybeare was founded.

† Principles of Geology, . . . . . vol. iii. p. 278, 8°. Lond. 1833.

‡ Mag. Nat. Hist., vol. viii. pp. 356, 357. (1835.)

§ Proc. Geol. Soc., vol. ii. no. 48, pp. 450-452, abstract.

|| Quart. Journ. Geol. Soc., vol. ii. pp. 223-259.

term plastic clay solely to the mottled clays (which term would probably be preferable) marked "b" [on the Plate] at Alum and White Cliff Bays," meaning thereby the clays beneath the true London Clay, as then established. He then goes on to speak of the few feet of sand etc. that there separates the mottled clay from the Chalk, as "the representative . . . of important and fossiliferous beds at the east of the London basin . . . This layer may be called the lower sands"; thus foreshadowing the lowest division of the Series, the Thanet Beds, to which however the Isle of Wight sand probably does not belong. He continues, "It is singular, that of all the varied beds of the tertiary series of England and France, the most persistent in its range, the most uniform in its composition . . . are these mottled plastic clays." He notices that this division "underlies the whole of the London basin west of London, ranging north to Hertford and Bishop Stortford."

Four years later appeared the first of the triple set of papers "On the Structure of the Strata between the London Clay and the Chalk,"\* in which PROF. PRESTWICH finally evolved order out of chaos, remarking that "although the relative position which the whole of the series of beds known as the *plastic clay formation* bears to the *London clay* and the *chalk*, has long been well-established, and is sufficiently apparent in several sections, the exact grouping and subdivisions . . . by which alone the precise co-relations of the strata can be determined, have not yet I think been clearly shown. These beds have in fact been viewed as one deposit irregularly interstratified . . . It has of late even been considered doubtful whether the larger original divisions into *London clay* and *Plastic clay* could be maintained." . . . The object therefore of this paper is . . . to show, that the variable series of deposits forming the lower tertiaries can be divided into distinct and separate, yet not altogether independent subdivisions, each marked by different conditions, indicating ancient hydrographical and palæontological changes of some importance." . . .

"This series is not large, yet it exhibits in different places variations in its structure and in its fauna, which render the determination of the exact parallelism between distant sections difficult," and he then notices the chief differences, putting the question "whether the whole of these series belong to one and the same group, occupying in an irregular manner this space in geological time, and varying in its thickness, in its mineral character, and in its organisms, without determinable order; or whether there are not subdivisions, each traceable over certain areas, and exhibiting essential modifications in structure, but yet invariably holding the same relative position."

Limiting the inquiry then to the topmost beds PROF. PRESTWICH suggests that the thin loamy pebbly bed at the base

\* *Quart. Journ. Geol. Soc.*, vol. vi. pp. 252-281. [The Basement-bed of the London Clay.] (1850.) The quotations are from pp. 253-255, 262, 278.



of the London Clay westward of London, etc., may "eastward assume a lithological structure . . . different from that of the London clay and not passing into it, but, on the contrary, assimilating so closely to the underlying sandy series, that in general appearance it seems an upper . . . member thereof . . . I believe, however, this bed to be part rather of the *London clay* than of the so-called *plastic clays* with which it has been grouped . . . yet it forms . . . a stratum separable from both."

In the detailed description of the sections, on reaching our south-eastern tract, the Professor says "The difficulty is, whether we are to consider any of the peculiar fossiliferous, sandy or conglomerate beds of Woolwich, Bromley, and adjacent districts as a fuller development of the basement stratum of the London clay, or whether they all belong to a distinct underlying series. I am rather inclined, on structural evidence, to the latter opinion; nevertheless, on palæontological grounds it might be presumed that a passage here exists between the two series."

In the conclusion it is noted that "from London . . . to Upnor, this bed [the sand and pebbles beneath the London Clay] reposes upon fossiliferous fluviatile beds, and here apparently there seems to be a transmission upwards . . . of some of the species . . . which abound in the estuary and fluviatile beds of Woolwich."

In the same year the REV. H. M. DE LA CONDAMINE gave a description of the Tertiary beds in the neighbourhood of Blackheath,\* with a map showing the following divisions of the 'Plastic Clay series.'

Pebble bed	-	-	-	-	[Blackheath Beds].
Striped sand and loam [a name adopted from Buckland].					} [= Woolwich Beds].
Shell bed	-	-	-	-	
Mottled clay, greensand and pebbles	-				
Ash-coloured sand and flints	-	-	-	-	[= Thanet Sand].

The next year† PROF. PRESTWICH said "This group I have temporarily designated merely as the *Lower Tertiary Strata*," a name soon given up however, and properly so, as it is really synonymous with the whole Eocene group. This term was used before in a paper which is really only a forerunner of the book quoted, and which was read in 1850‡ and may have been published in that year.

In 1852 PROF. PRESTWICH's second paper on this set of beds appeared§ in which the name Thanet Sands was given to the

\* *Quart. Journ. Geol. Soc.*, vol. vi. pp. 440-449. (1850.)

† A Geological Inquiry respecting the Water-bearing Strata of the Country around London . . . p. 12. 8°. Lond. 1851.

‡ On the Geological Conditions which determine the Relative Value of the Water-bearing Strata of the Tertiary and Cretaceous Series . . . *Proc. R. Inst. Brit. Architects*.

§ *Quart. Journ. Geol. Soc.*, vol. viii. pp. 235-264. The quotations are from the first three pages.

lowest member. Of the whole he says that "a careful examination of these strata has led me to believe . . . that a regular and definite order of superposition does exist, and that, instead of one series of alternating and intercalated strata, the conditions of structure and changes in the fauna show that there are five well-marked and distinct groups. Three however of these groups are apparently synchronous." The objections to the old name of "Plastic Clay Formation" are enforced and the following classification is suggested.

The Lower London Tertiaries.	{	The Basement Bed of the London Clay.
		The Woolwich and the Mottled Clays, Sands, and Pebble Beds.
		The Thanet Sands.

"The sands which in Kent immediately overlie the chalk are here formed into a separate division, as I believe them to be entirely of marine origin, and distinct from the sands incumbent on the chalk . . . westward of London, but with which these Kent sands have been hitherto considered synchronous . . . it is from the gradual thinning out of the latter, as they range westward, and not by actual synchronous deposition that this mottled clay group reposes immediately upon the chalk."

The same year the eminent Belgian geologist A. DUMONT gave a somewhat elaborate classification of the "Plastic clay" of the London Basin,\* making 13 divisions, in 5 groups, as below. The lowest of these is merely the layer of flints next above the chalk; the rest have their equivalent group-names added in square brackets, as far as I am able to understand them; but the order is not altogether recognisable and there seems to be some error in the top two groups. Perhaps no better evidence of the inconvenience of the name Plastic Clay, as used here for the whole series, could be given, that particular material being mentioned only in one of the sub-divisions. The figures against some of the beds presumably mean thickness in feet.

[? Mixture of Blackheath and of Woolwich Beds.]	{	Sandy clay, glauconiferous clayey sand, 1—30.
		Mottled plastic clay and a trace of lignite.
		Sand of moderate grain.
		Pebbles and pebbly fossiliferous limestone.
[Woolwich Beds.]	{	Fossiliferous bed and quartziferous shaly clay.
		Limonite.
		Glauconiferous sand and beds of shaly clay.
		Pebbles.
[Thanet Beds.]	{	Sand of moderate grain (silexifère = with flints ?) 1—25.
		Clayey sand (silexifère, = with flints ?), 1—10.
		Glauconitiferous psammite, 1—10.
		Psammite (silexifère, = with flints ?) $\frac{1}{2}$ Kidney-shaped flint.

In 1854 the most important of PROF. PRESTWICH's three papers on this set of beds appeared.† In this he describes the

\* *Quart. Journ. Geol. Soc.*, vol. viii., table opp. p. 370. (1852.)

† *Quart. Journ. Geol. Soc.*, vol. x. pp. 75—170. The quotations are from pp. 75—77, 130, 135.

middle member, "the one which more particularly embraces the beds which have hitherto been described as the "*Plastic Clay Formation*," exhibiting in one part of its range the mottled clays . . . . . and, in another, the clays and sands, with fluviatile and æstuarine shells." After noticing how well the chief sections had been described, he goes on to say that "nevertheless the correlation of the beds at the different sections has not . . . . . been correctly shown," and he alludes to the fact [even now ignored] that though in many places "near London where the mottled clays show themselves, these . . . underlie the Woolwich shelly clays," yet "this relative position is not permanent, for another and larger portion of the "mottled clays" set in upon these Woolwich beds as they trend westward from London."

He notes the more uniform characters of the divisions above and below, and says that the middle division is "in different areas so very different in its lithological structure and in its organic remains, that it presents one of those cases where the evidence of superposition is indispensable. Were it not for the well-marked horizons afforded by the upper and lower divisions, which confine this group within distinct limits, it would in fact often be difficult or rather impossible to identify its synchronous beds, when viewed in detached sections, either by their mineral or palæontological characters alone. It is this feature which forms one of the chief points of interest of the group, for if it is important to identify strata by their organic remains or by their lithological structure, it is not less so to trace the changes of composition which can occur in strata on the same plane, to note the modifications in the fauna by which such changes are accompanied, and to determine the limits to which the variations may extend. The case now before us is, so far as it regards the dimensions of the deposit itself, one comparatively of small importance, but it is valuable from the clear and unmistakable testimony which it affords on these points. It was the extremely variable character of this group, which putting on occasionally the appearance of the group beneath, and at other times assuming the character of the one above it, that led to the impression of a want of order and of irregularly occurring strata throughout the whole of the Lower [London] Tertiaries. So deceptive, indeed, are these common points of structure, that it is only lately that I have been able to satisfy myself that these changes are confined essentially to one portion of the series, and that one restricted to the limits of the middle division, and that strata so very dissimilar are really equivalent. This once determined . . . it becomes apparent that there is in the "Lower London Tertiaries" a defined order of superposition . . . of three distinct and independent groups of strata."

Recurring to the middle division, PROF. PRESTWICH continues "that it is by actual alteration in some of its beds . . . . . as much as by the thinning out of others, that these changes are produced . . . Under these circumstances there are objections to giving this division a simple designation dependent either

on mineral character or on place, for the former is constantly varying, and the type of the series in one district may be entirely different in another. Still a name taken from some well-known place is . . . the more convenient, and I purpose therefore to term this division the "Woolwich and Reading series," as the two principal forms of structure are well exhibited in the sections at and around these localities."

Many details of sections and of structure are given, and, in a footnote, the author expresses a doubt "whether some of the thick pebble beds . . . around Shooter's Hill may not belong to the upper part of the Woolwich series, rather than to the Basement of the London Clay," and says "It is also difficult to say positively whether some lower portion of the Reading series may not possibly be synchronous with the Thanet Sands . . . these doubts . . . however, do not affect the superposition and grouping of the three divisions here proposed, although it [they] would modify the exact lines of separation."

He remarks that "not only are the several members of the "Lower London Tertiaries" divided by irregular surfaces, but the Woolwich series itself often presents in its central area instances of its several beds being deposited upon slightly eroded surfaces one of another."

To the popular account of his researches, given by PROF. PRESTWICH in 1857, we need only refer.\* It was the only publication referring to our subject between his great paper of 1854 and the work of the Geological Survey.

In 1861 the writer ventured to replace the term "Series," for the middle member of the Lower London Tertiaries, by the less important term "Beds,"† and the next year to express an opinion that the thick Blackheath pebble-bed might be the top part of the Woolwich Beds rather than the basement-bed of the London Clay, which last seemed to be represented by a thin clayey pebble-bed above the first.‡

Two years later I continued in the same faith,§ and used the looser term "Beds" instead of the more precise (and not always fit) term "Sand," for the lowest member.

In 1866 I gave an account of the result of the Geological Survey work over the Tertiary beds of Kent,|| attempting to trace the component parts of all three divisions of the Lower London Tertiaries. It had been found that the pebble-beds and sands between the London Clay and the Woolwich Beds were distinctly mappable, separately from either of those formations; so that it was needful to give them a name. To call them the Basement-bed of the London Clay seemed a mistake, as they could so easily be divided from that deposit, and moreover Prof.

\* The Ground beneath Us . . . . 8°. Lond., pp. 56-75.

† Memoirs of the Geological Survey . . . . The Geology of Parts of Oxfordshire and Berkshire, p. 22.

‡ *Quart. Journ. Geol. Soc.*, vol. xviii. p. 267.

§ *Geologist*, vol. vii. pp. 58, 59. (1864.)

|| *Quart. Journ. Geol. Soc.*, vol. xxii. pp. 404-435, pl. xxii.

Prestwich, who gave that name, had grouped the beds with the Lower London Tertiaries, and not with the London Clay. It was proposed therefore to limit the name Basement-bed to those thin loamy and pebbly layers that always occur, more or less, at the base of the London Clay, and which pass up into it, and to give the name "Oldhaven Beds" to the thicker mass of pebbles and sand, in Kent, which was found to be separable in mapping. In that group moreover was included the shelly conglomerate near Bromley, etc., as it was taken to be merely another condition of the sandy, and usually unfossiliferous pebble-beds, rather than to belong to the underlying Woolwich Beds, with which it had been classed.

In treating of the relations of the three divisions to each other the conclusion come to was that, in Kent and in the border of Surrey, there was evidence of a southerly transgression (which term was used instead of unconformity) of the Woolwich Beds over the Thanet Beds and of the Oldhaven Beds over both, this highest member markedly overlapping the others, until it rests on the Chalk.

After the publication of this paper the Lower London Tertiaries had rest for six years, when the above conclusion was enforced in the Memoir on the London Basin,\* and the following remarks were added:—"As it was decided to colour this division of the Lower London Tertiaries on the Geological Survey Maps, its boundary-line being added to those sheets (1 S.W., 6 and the eastern margin of 8) on which it was not at first engraved, a name had of course to be given to it, and the one I had suggested was taken. The name of the better known place Blackheath might perhaps have been more conveniently used, but there would be no use in changing the name now, although from the Series being rather differently composed in West and East Kent the compound "Oldhaven and Blackheath Beds" might be used for this—the highest and most local division of the Lower London Tertiaries."

The Chapter was accordingly headed "Oldhaven (and Blackheath) Beds."

As, after this time, some of the papers on the subject are in part criticisms of the Geological Survey Memoir, it will be convenient in noticing them to answer the objections made, and to put right any mistake that may have occurred.

In 1875 two short general accounts of the series were given, one by PROF. MORRIS,† the other in a Geological Survey publication,‡ in which the Blackheath Beds are spoken of as "formed in a changeful area of sea invaded by fresher water, and the reverse," which clearly acknowledges estuarine conditions.

\* Memoirs of the Geological Survey of England and Wales, vol. iv. p. 39. (1873.)

† Lectures on the Geology of Croydon, in relation to the Geology of the London Basin. (*Croydon Micr. Club.*)

‡ Guide to the Geology of London and the Neighbourhood. Ed. 2 also in 1875, Ed. 3 in 1880, Ed. 4 in 1884.

The following year an account of these beds in the neighbourhood of Lewisham and Charlton was given by DR. H. J. JOHNSTON-LAVIS.\* In this paper (p. 538) there are two slight misunderstandings of my own work, which may as well be put right. I have not said that the Blackheath Beds "were formed on an old shingle-bank which was well out at sea," the expression used was "some way off the shore;" but what shore was not said, nor did I infer marine action. My statement therefore is not contradictory to a list of estuarine fossils. Again the Oldhaven Beds were not divided from the London Clay, at Herne Bay, "entirely on palæontological grounds:" on the contrary I was led to make the division on account of the great lithological difference between the two, and should probably have mapped the sand there even had every fossil in it been of a species that occurred in the clay above.

PROF. MORRIS also published another general notice,† and was followed, in 1877, by MR. J. L. LOBLEY.‡

In 1879 MR. J. S. GARDNER referred to these beds in a general paper "On the British Eocenes,"§ with reference to their floras. He regards the mottled clays as "the first evidence of the presence of a great river flowing from W. to E., and scouring and draining a granitic country," and continues thus:—"In the estuarine beds with lignites around London, belonging to the same series, we can trace its delta, whilst the marine sands in the east . . . have been thrown down by the Northern Sea, into which it flowed." He goes on to say that the "movement at the close of the Woolwich and Reading Beds was probably one of slight upheaval, during which the south-east of England became land. Depression followed, and the Northern Sea gradually re-occupied the tract" . . . the OLDHAVEN BEDS . . . are the result of the littoral conditions which prevailed during the recession . . . The remarkable extent to which the flints are worn shows that the duration of these conditions was very considerable, whilst the change in the fauna seems also to indicate a great lapse of time," a conclusion with which one is hardly disposed to agree, the whole series probably not having needed a large amount of (geologic) time.

Three years later the same author gave a revised classification of the British Eocenes,|| in which, throwing the London Clay into the Middle Eocene, he uses the following terms:—

Lower Eocene - { Oldhaven Series.  
Woolwich and Reading Series.  
Thanet Series.

He adds that "the Lower Eocene group . . . is singularly homogeneous . . . This group consists of sediments of marine, littoral, estuarine and freshwater origin."

\* *Proc. Geol. Assoc.*, vol. iv. no. 9, pp. 528-543. (1876.)

† *Trans. Watford Nat. Hist. Soc.*, vol. i. pt. iv. p. 89. (1876.)

‡ *Ibid.*, pt. vii. p. 161.

§ *Proc. Geol. Assoc.*, vol. vi. no. 2, p. 83 (pp. quoted 85, 86, 91-93).

|| *Geol. Mag.*, dec. ii. vol. ix. p. 466. (1882.) Pages referred to 467-469.

He includes the sands that have been mapped as Woolwich Beds in East Kent, and the Oldhaven sands above, with the Thanet Beds, as but minor subdivisions of a single and continuous formation, and then goes on to say that "this great marine deposit is traceable westward in the ancient beaches known as Oldhaven deposits . . . . It is obvious that such extensive tracts of beach or shoals could only be produced by continued retrogression of the sea, and the beaches furthest inland would be the oldest. There is absolutely no reason that I see at present why the vast accumulations of shingle at Bickley and elsewhere should not be contemporaneous with the sea deposits of Herne Bay, even though they were actually traceable as a horizontal formation directly overlying the Herne Bay formation. Beaches are the last sediments that can be left by a receding sea in an area of elevation; and to consider the Lower Eocene beaches as a distinct formation, except lithologically, can only delay any appreciation of the real conditions under which our Eocene strata were formed. The Oldhaven division, I submit, should only be recognised as one of quality—not time—partially overlying and overlapping the marine beds of the Thanet sands" [? of East Kent]. The "lithological distinctness" of the chief pebble-bed (? not beach) above alluded to is surely the best of reasons for mapping it.

"The classification of the Lower Eocenes is greatly complicated by the intercalation of deposits, both brackish and purely freshwater, formed in a river estuary. These are the Woolwich and Reading Beds . . . . While the great mass of the Oldhaven Beds show a retreating sea, these estuarine beds [of Woolwich] show encroaching salt water ushering in the London Clay Sea, without any intervening beach." This I do not understand, as the estuarine beds in question are often separated from the London Clay by the thick mass of the Blackheath Beds (pebbles and sand).

MR. GARDNER continues "The Lower Eocene of England is thus a well-marked division, consisting of fluviatile beds [mottled clays, etc.] in the west, passing east into estuarine, and finally into marine beds. These conditions . . . doubtless were contemporaneous to a great extent, but the divisions into which they are classified must rather be held to mean distribution of quality or origin than an absolute sequence in time."

I am inclined to doubt whether so small a set of deposits as those in question, is entitled to form a separate division of the great Eocene series by itself, and to be thus divorced from its natural upward continuation, the London Clay, though our author says that the latter "marks such an enormous change both in the area of land and in climate, that it becomes an anachronism to place it with the preceding group," a conclusion which he hardly adhered to for a year, when he joined the Oldhaven Beds to the London Clay, as may be seen from the following.

In a paper specially devoted to the Reculvers section,\* MR. J. S. GARDNER made, in 1883, various remarks of a general

\* *Quart. Journ. Geol. Soc.*, vol. xxxix. p. 197. (Pages noticed 197, 202, 205, 207-209.)

character. His objection to the name "Oldhaven," as one that "does not exist on the maps" is distinctly mistaken; for it is the one given to the place on the old one-inch Ordnance Map (Sheet 3), which was the only version in existence at the time the Geological Survey was made, and the name was given to the group of beds. The further objection that the name Oldhaven "is scarcely known at the locality" seems to me of small importance, in view of the above fact.

The Geological Survey has not classed the whole of the Oldhaven Beds as marine (as the author infers), but has included therewith more estuarine beds.

Our author says, "There are no beaches throughout the Eocene with a proportion of angular flints, such as we invariably see when flint beaches are immediately derived from the chalk; nor are there any indications of old chalk cliff-lines . . . The fluviatile deposits show that no chalk was being cut through by the river, and the marine deposits that no chalk was being planed down on this area by the sea. The chalk cliffs of the Eocene coast-line must therefore . . . have been far distant."

One of the reasons given for including the sand that has been mapped as belonging to the Woolwich Series in East Kent with the Thanet Beds, is based on a mistake. The author says that "at Pegwell Bay a layer of black flint pebbles occurs in what is acknowledged to be Thanet Sands." The layer in question is really at the base of the Drift Brickearth, and has not been acknowledged to belong to anything else; Mr. Gardner indeed himself infers this in his plate, though only saying "apparently classed as drift." The statement (on the plate) that it is "not mentioned by Prestwich on the Survey" is incorrect, for it has been mentioned by both, as Drift. It should be noted that this section has been much cleared since the Survey was made; having however seen it in 1885, I have no doubt about the question.\*

Speaking of the Oldhaven sands, the author says that they "belong palæontologically to the London-Clay series. The Oldhaven Beds might fairly be considered . . . to be a lower member of the latter series, as, indeed, was implied by Prestwich's name," thereby practically giving up his proposed classification of the year before, in which these beds were distinctly separated from the London Clay.

He then continues: "The upper portion of the marine Thanet Beds of this part of Kent may have been, and probably was, to a slight extent contemporaneous with the fluviatile Woolwich-and-Reading Beds of further west . . . I should most decidedly place the base of the Woolwich-and-Reading Beds at this horizon [the bottom of the mottled clays], and consider all the marine shingles and sands below the plastic clay an integral part of the marine Thanet formation . . . There is not the remotest reason, that I can discern, for separating these from the underlying series and making them a marine member of the overlying fluviatile series." It seems rather a pity that the author has used such very decided language; surely the

\* *Proc. Geol. Assoc.*, vol. ix. no. 4, p. 173.



stratigraphical reasons advanced by PROF. PRESTWICH and enforced by the Geological Survey, are not absolutely valueless, and is there reason to think that fresh and brackish waters were universal during the Woolwich period? Does not the occurrence of an estuary point to the nearness of sea? Our own modern alluvial deposits show alternation of freshwater and marine conditions: Why should not those of the past?

MR. GARDNER's idea that the Woolwich and Reading Beds can be separated into an upper Woolwich Series and a lower Reading Series, seems to ignore the fact that though the mottled clays are chiefly found underneath the Woolwich shell-beds (when the two occur together), yet another mass of mottled clays has sometimes been found above those shell-beds, clearly proving a dove-tailing of the two deposits.

"The Thanet Beds were probably deposited . . . by a rough sea in an area out of the immediate estuary of the river, but within its influence. The area became silted up until it finally rose above the surface and became covered over with shingles and sand. The Thanet Beds close with a period of elevation, during which the Reading Beds were formed; and these were followed by a subsidence during the Woolwich period, which finally ushered in the Oldhaven and London Clay deposits. The Oldhaven Beds may represent some such action (but under a rougher sea) as that which now forms the beach at Shellness." My reasons for differing from MR. GARDNER, and for holding to the older classification were given briefly in the discussion on his paper, and later, whilst conducting an excursion to the Reculvers coast,\* and will be found in the following notice of Mr. Harris' paper of 1887.

In 1887 Mr. Gardner's views were ably supported by MR. G. F. HARRIS,† from whom however I differ as to some questions of fact. This author parallels the laminated sand *above* the thick pebble-beds (of the Blackheath Series) at Croydon (see p. 130) with that which is *below* the thin pebble-bed (which he takes to represent the other) at Lewisham (see p. 154). Moreover, further eastwards at Charlton, not only is the continuation of the Lewisham sand seen below the Blackheath pebble-beds but also the former has been eroded before the deposition of the latter (see p. 148). One laminated sand therefore (Croydon) belongs to the Blackheath Beds, whilst the other is part of the Woolwich Beds (Lewisham, etc.): two different beds have been taken as the same.

I cannot understand how any doubt can be felt as to the exact position of the Blackheath pebble-bed, which is between the London Clay and the Woolwich Beds. The base of the pebble-beds is to be seen, and the top has been seen, and perhaps may still be seen at one place (Erith, see p. 231).

\* *Proc. Geol. Assoc.*, vol. ix. no. 4, p. 170. (1886.)

† *Proc. Geol. Assoc.*, vol. x. no. 2, p. 40. (Pages referred to 43, 45-47, 49, 50, 52-57.)

It seems to me that Mr. Harris is mistaken in his reading of the sections near Canterbury, having classed as representing the Woolwich shell-beds, etc. what, to me, clearly belongs to the overlying Oldhaven Series; but this is beyond our present district, and needs no further notice here.

I must be allowed to disclaim the name "Lower London and Kentish Tertiaries" credited to me. All I did was to suggest "Kentish" as an alternative to "Lower London," not as an addition, and ever afterwards was content with Prof. Prestwich's term.

Nor can I accept the statement of my holding that the Blackheath pebble-beds were deposited "a little way out at sea;" as before noted, my words need not imply marine action.

If the bed of green-coated flints, at the base of the Thanet Sand, is, as our author allows to be possible "forming at the present day," that hardly seems to tally with his suggestion "that it should be classed with the Cretaceous beds below." As the green-coated flints are more or less enveloped in the greenish loamy matter of the Thanet base-bed, surely it is better to let them go with it, and not vainly to seek to return them to the Chalk.

MR. HARRIS follows MR. GARDNER in extending the Thanet Beds so as to include the bottom-bed of the Woolwich and Reading Series; but why the occurrence of marine shells in this bed, which is quite an occasional matter in our district and to the west, should be allowed to decide this, I do not understand; it seems to me that such an argument is highly elastic, and might be stretched firstly so as to take in the well-known oyster-bed of the Woolwich shelly clays, and then the marine beds of the Oldhaven Series. Why the Woolwich and Reading Beds should not be allowed to have a marine member passes my understanding; indeed it seems to me that their estuarine member must somewhere have got to marine conditions! and when that happened it is not unlikely that there might sometimes be a passage into the underlying marine Thanet Sand. The question however whether a certain bed should be classed as the top of the Thanet or as the bottom of the Woolwich Series is one of small importance, and one in which individual feeling may be allowed free play.

It should be remembered that the occurrence of pebbles in the "bottom-bed" shows that the water which deposited it must have spread across the whole of the underlying Thanet Beds (not only the part present in our district, but also the higher fossiliferous beds of East Kent) on to the Chalk, from the flints of which the pebbles were formed; for there are none ready-made in the Thanet Beds.

It may be doubted whether "the creation of the Blackheath series is largely dependent on the value of the evidence afforded by this pebble-bed" as to unconformity with the beds below. That series was given a name because the beds composing it were found to be distinctly mappable, from East Surrey right through Kent, whether resting evenly or irregularly on the division below.

That pebble-beds belonging to a lower part of the Lower London Tertiaries should have been mistaken for these Blackheath Beds (as MR. HARRIS suggests) is very unlikely. Such pebble-beds are of rare occurrence (in the Blackheath district), excepting for the pebbly greensand at the base of the Woolwich Beds, the matrix of which is unlike the fine buff sand of the thick wide-spreading Blackheath Beds: moreover, where such pebble-beds occur, they are comparatively thin, and they are below the shelly clays, whereas the great mass of Blackheath, etc. is above the last. That some "of the shingle has been slightly shifted by various agencies in recent times" is a matter of course, and, where no sections occur, such a thing may give rise to some slight errors in drawing a boundary-line; such errors being of a kind that the most careful mapper of loose beds cannot avoid; but in this district they must be trifling, and they can have no effect on the general question. When Mr. Harris says "I cannot think that the mere circumstance of an estuarine pebble-bed having cut its way through a few feet of deposits, and resting irregularly on another . . . deposit, is sufficient grounds for showing an unconformability," he will find few, if any, geologists to disagree with him: for my own part, I have preferred to use the word "irregularity" for such an occurrence, keeping "unconformity" for something greater; indeed in speaking of the greater irregularity by which the pebble-beds in question have been brought to rest directly on Chalk, and even on far from the top beds of that formation, I have used the words "overlap" and "transgression" rather than unconformity.

MR. HARRIS goes on to say that the fossils of the Blackheath pebble-bed "are almost identical with those of the Woolwich and Reading Series below, and there is, therefore, no reason for separating the two deposits," a conclusion with which I cannot agree; the two deposits being distinctly separable as a question of mapping (without any regard to their fossils) there is great practical advantage in separating them, as has been done on the Geological Survey Maps.

With regard to the marine Oldhaven Sand of East Kent, MR. HARRIS differs from MR. GARDNER, and classes it with the Woolwich and Reading Beds instead of with the London Clay. It seems to me that the fact that these authors cannot agree as to this set of beds, one giving them to the formation above and the other to that below, is a very good reason for adopting the middle course suggested by me, and treating them separately from either! When it is doubtful whether any set of beds are more closely allied to those above or to those below, the best course to take is to class them with neither, but be content with stating the fact of their intermediate position, which is really all that I have done.

I have submitted this point to my friends MR. T. V. HOLMES and MR. J. G. GOODCHILD, who know the Blackheath district well, and it is curious that, whilst agreeing with me as to the advisability of treating the pebble-beds separately from either

London Clay or Woolwich Beds, they differ in opinion as to the matter of alliance with the underlying or overlying formations.

Though averse to engaging in controversy I have felt obliged to do what little is possible to controvert some of the remarks of MR. GARDNER and of MR. HARRIS, and to justify the work of the Geological Survey; to do otherwise indeed would be most uncomplimentary to those gentlemen, whose papers are founded on long-continued labour, and whose aid in working out the history of these interesting beds is most acceptable.

In the current year PROF. PRESTWICH has given us his latest views on our Eocene formations, in a paper "on the Correlation of the Eocene Strata in England, Belgium, and the North of France,"\* and it is very pleasing to the writer to conclude this historical review with a notice of the work of the geologist who has done far more than any other in this subject. He upholds his former view that the fossiliferous pebble-beds of the Blackheath and Bromley districts should be grouped with the Woolwich Beds, rather than with the overlying division, but says "I felt originally some difficulty about part of the series; and my view of it may still admit of discussion on stratigraphical grounds. It is, however, supported by the palæontological evidence, although, as so many species are common throughout all the divisions of these Lower Tertiary beds . . . that evidence is not strongly marked." Unfortunately however the list of fossils from these pebble-beds has been included in that from the Woolwich Beds, whilst the list from the Oldhaven Beds of East Kent has been included with that from the Basement-bed of the London Clay: so that we are not able to compare those lists. PROF. PRESTWICH writes to me however that the Oldhaven list was taken from that in the Geological Survey Memoir (vol. iv.).

It will be seen that our author's conclusion is based largely on the fossils. Now the Geological Survey had to approach the question more from the stratigraphical, or one might say from the mapping, point of view. The whole mass of the pebble-beds south-east of London forms one great continuous sheet, in most parts without trace of fossils: How then is any division to be made in it? Clearly it must all be mapped together, and, as it forms a distinct feature, and is distinctly separable from the beds below (as a matter of mapping) surely it is but wise to acknowledge that fact on the map.

PROF. PRESTWICH continues, "I feel there is now an objection to the use of the term Basement-bed. So long as it was confined to a few feet at the base of the large formation [London Clay] of which it seems to form part, the term was suitable; but if, as in this case it promises to do, it becomes more important and individualized, it is better to use a more distinctive term." He accepts that of Oldhaven Beds, with the limitation proposed and above-noted, and in the table of classification proposed the series stands thus:—

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\* *Quart. Journ. Geol.*, vol. xlv. pp. 88-111, pl. v.

Oldhaven or Basement-beds.  
Woolwich and Reading Beds.  
Thanet Sands.

In the same author's great work,\* published just after, but probably written before the paper, the highest division is massed with the London Clay.

In conclusion I am glad to say that PROF. PRESTWICH approves of the use of the term Blackheath Beds for the pebble-beds of that district.

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\* *Geology* . . . . . vol. ii. pp. 6, 336. 8°. Oxford. 1888.

## CHAPTER 8. LOWER LONDON TERTIARIES (THANET SAND).

### GENERAL REMARKS.

#### *Structure.*

The distinctness of this formation, from the overlying Woolwich and Reading Beds, was proved by PROF. PRESTWICH, and one cannot do better than quote his description:—"The mineral structure of this deposit is very simple. It consists essentially of a base of fine light-coloured quartzose sand, mixed, in its lower beds more especially, with more or less argillaceous matter. . . . It also contains a small proportion of dark green grains, which sometimes give to these beds, otherwise on the whole of a very light yellow or stone colour, an extremely slight ash-green tinge; but in the stratum, 2 to 6 feet thick, immediately lying upon the Chalk, they so predominate as to form an impure argillaceous greyish greensand, very constant in its position and characters. Examined through a microscope, the grains of sand appear colourless and subangular, worn, but not rounded. . . . The argillaceous matter is usually light-coloured, and does not therefore colour the sands, merely giving a certain amount of cohesion. In some places however the clay with which the sands are mixed is darker coloured. . . . A distinctive feature of this division is that it never contains layers or beds of those rounded black flint-pebbles so common in the overlying divisions, nor does it ever exhibit subordinate beds of those mottled clays which so well mark the middle division [the Woolwich and Reading Beds]. . . . A very marked feature of the "Thanet Sands" is the constant occurrence at the very base of the deposit, and immediately reposing on the Chalk, of a layer of flints of all sizes, just as they occur in the underlying Chalk, from which in fact they appear to have [been] removed comparatively without wear or fracture; for they are almost as perfect as the undisturbed flints, but present this difference, that instead of their usual white or black coating, these flints are almost invariably of a deep bright olive-green colour externally. . . . There is on the whole in the Thanet Sands a uniformity and breadth of character entirely wanting in the overlying division of the Lower Tertiaries, which deposit is on the contrary extremely variable in its structure, showing rapid changes within short distances and great variety of lithological composition. This well maintained regularity in the one, whilst the accompanying overlying beds undergo at the same time considerable alteration, is in fact one of the features which serves to mark the two divisions."\*

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\* *Quart. Journ. Geol. Soc.*, vol. viii. pp. 242-244. (1852.)

In carrying on the Geological Survey through Kent, I was led to regard the Thanet Beds as a succession of deposits, the upper fossiliferous parts of which occurred only in the eastern half of the county, where the formation reaches its greatest thickness, whilst westward it is represented by a lower part (which on the other hand thins out eastward), the clayey base-bed alone occurring throughout.

In our district we find only a sand, above the base-bed, and that sand seems to thin out west of Canterbury; but beyond our district there comes on above this sand a sandy marl, and then above that another sand, which two, thickening eastward, at last make up nearly the whole of the formation.\*

As we are dealing with sand only, except for the thin base-bed, the term Thanet Sand is used in this Memoir, instead of Thanet Beds, which would be used for the whole of the division.

From an examination of the quartz grains of the upper part of the Thanet Sand at Croydon, MR. H. M. KLAASSEN shows that they are angular and subangular, and he gives measurements varying from  $\cdot 003$  to  $\cdot 009$  of an inch in length, from  $\cdot 001$  to  $\cdot 008$  in breadth, and from  $\cdot 0008$  to  $\cdot 005$  in thickness. He then remarks that "the angularity and the difference between length, thickness, and breadth, indicate that the sand was not rolled along, the particles being suspended in agitated water, and then spread by tidal action and marine currents. Most of the quartz grains are colourless and transparent, but a few are of different shades of yellow, orange and red, due to hydrated ferric oxide deposited on their surfaces. . . I have not found any cryptocrystalline silica indicating the presence of flint-particles. . . . There are a few grains of mica, granules of oxide of iron and green, dark green, and black grains [glauconite], with rounded outlines, which crush into a fine amorphous powder. . . In the lower portion the quartz grains are subangular, and there is less difference in their length, breadth, and thickness. A greater per-centage here is coloured, some of the red grains being very brilliant. . . Mica is scarcer and green grains with rounded outlines are more abundant."†

#### *Layer of green-coated Flints at the Base.*

In 1836 DR. J. MITCHELL drew attention to "a description of flints found in beds immediately over the chalk, and below the sand, in all the places where these strata are seen to meet," named places in Surrey Kent and Essex where he had seen this junction (of Thanet Sand and Chalk), and noted the name "iron flints" as given to this bed at Purfleet. Of these he says:—"The exterior is covered with a rough black [= dark green] crust, which is found to be a combination of silex and oxide of iron . . the oxide of iron is found to penetrate about a

\* See *Geological Survey Memoirs*, vol. iv. p. 56. (1872.)

† *Proc. Geol. Assoc.*, vol. viii. no. 4, pp. 228, 229. (1883.)

quarter of an inch all round . . . these flints . . . do not yield flakes in any direction so readily as the chalk flints . . . I have been informed by two gun-flint makers that such flints afforded the best sort of gun-flints for gentlemen's fowling-pieces; but being less easily made than the gun-flints from the chalk flints, and the material being less abundant, they were more expensive."\*

The unworn character of the flint-bed that everywhere rests on the Chalk led PROF. T. MC. K. HUGHES and myself to think that it may have been formed after the deposition of the beds above, by the dissolving away of the Chalk and the consequent leaving behind of its contained insoluble flints. As my former colleague worked out the question at some length, I give the reasons for the conclusion in his words (although based on sections chiefly beyond our district).

"The following observations have led me to infer that this bed is due to the decomposition of the top of the Chalk after the deposition of the Thanet Sand."

"1. The flints never show any traces of having been rolled or worn by the action of water, or broken up and weathered by any subaërial agency, but are, except in colour, exactly similar to those in place in the Chalk."

"2. No fossils, except chalk fossils preserved in flint, have been found in it."

"3. Where a nearly continuous bed of flints, or a large tabular mass of flint occurs, the base-bed of the Thanet Sand seems to be arrested by it in a manner that would suggest rather the chemical decomposition than the mechanical erosion of the surrounding chalk."

"4. Where masses of chalk are embedded in or surrounded by the base of the Thanet Sand they appear to be due to local undermining of the main mass of the rock, and not to be transported fragments re-arranged in a hollow."

"Again to look at the question from another point of view, it is highly improbable that it could be otherwise. As water charged with carbonic acid, soaking through the Thanet Sand, reaches the chalk below, it must decompose the surface to a certain extent; and if the water can pass freely away so that new supplies, not saturated with carbonate of lime, are brought to act upon it, that decomposition must go on *ad infinitum*."

"The only difference therefore between this action extending over the whole surface of the Chalk where covered by Tertiary or later deposits and that which forms pipes is, that in the case of the pipes the water is collected at or near the surface into small streams; whereas in the other case it permeates the whole deposit overlying the Chalk, and acts more equally on its surface."†

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\* *Phil. Mag.*, n. ser., vol. ix. pp. 356-358. (1836.)

† *Quart. Journ. Geol. Soc.*, vol. xxii. p. 402. (1866.)



The green-coating of the flints must be owing to the deposition of a salt of iron from the water; and the *allophane* (a hydro-silicate of alumina) that has been noticed as occurring at the junction of the Thanet Beds and the Chalk at Charlton (see p. 147) would seem to have been formed in a like way, from the infiltrating water. Of this mineral PROF. MORRIS says that "it must have been deposited from a fluid or viscid state, not only after the denudation of the Chalk and the deposit of the partially abraded [?] flints, which are coated with it, and after the accumulation of the Thanet Sand, but subsequently to the disturbance of the whole series, whereby the fissures in the Chalk were formed, and in which the allophane is now found.\* I have since found it at the same junction elsewhere in Kent, and I believe that it occurs at the junction of the Reading Beds with the Chalk at Northaw (p. 207), the same position as that of Websterite (a subsulphate of alumina) at Newhaven in Sussex.

It is remarkable that whatever bed rests on the Chalk, there should nearly always be unworn flints at the junction; in the western part of the London Basin there are flints at the bottom of the Reading Beds, which there rest on the Chalk; and in the many districts where the Chalk is covered by a deposit of brick-earth (over the high grounds) the two are separated by the "clay-with-flints," the origin of which MR. CODRINGTON and myself have independently referred to the slow dissolution of chalk by carbonated water (see *post*).

MR. G. DOWKER has suggested that the bed of green-coated flints may be owing rather to subaërial dissolution of the Chalk before the deposition of the Thanet Beds.†

PROF. MORRIS accepted our view, saying of the "Bull's-head Bed," as it is termed, that "these unrolled and unmoved flints formed one of the original zones of flint in the Chalk, from which the latter has been removed by chemical action either before, but more probably subsequently to, the deposition of the Thanet Sand, during which they also acquired the green coating of silicate of iron."‡

MR. J. S. GARDNER has suggested that the peculiar character of the greenish sediment in which the flints are enveloped may have been caused by imbedded sea-weed, and says that this layer "might of course belong to a very much older period than the rest of the Thanet Beds.§

MR. G. F. HARRIS remarks that this green clay, etc. seems "to be largely the particles of impurities, &c. brought through the sand by the action of water, which on arriving at the Chalk was filtered, and so the particles were left behind. Some of it may be . . . the remains of insoluble matter, other than flint, which was contained in the Chalk itself."¶

\* *Quart. Journ. Geol. Soc.*, vol. xiii. p. 13. (1857.)

† *Geol. Mag.*, vol. iii. pp. 210, 289. (1866.)

‡ *Trans. Watford Nat. Hist. Soc.*, vol. i. pt. iv. p. 92, footnote. (1876.)

§ *Quart. Journ. Geol. Soc.*, vol. xxxix. p. 202. (1883.)

¶ *Proc. Geol. Assoc.*, vol. x. no. 2, p. 52. (1887.)

*Junction with the Chalk.*

In every large section this junction is even, and no unconformity is shown between the two formations, as noticed in 1836 by DR. J. MITCHELL, who remarked that "in most of the localities examined the surface is perfectly level, even, and unbroken; and it is not furrowed and indented as some observers have represented the upper surface of chalk always to be."\* Where however there is but a thin capping of the Thanet Beds, it often fills "*pipes*," irregular-shaped hollows that have been formed, since the deposition of the beds, by the infiltration of water with carbonic acid in solution, which, slowly dissolving away the carbonate of lime of the Chalk, forms more or less funnel-shaped hollows into which the overlying sands, &c. sink. MR. J. TRIMMER held to the belief that these hollows were worn out in the Chalk before the deposition of the next overlying formation,† but I think that all Tertiary geologists now agree with the views of SIR C. LYELL,‡ DR. BUCKLAND,§ and PROF. PRESTWICH,|| as given above. The fact that where the Chalk is more thinly covered, and therefore less protected from the chemical action of carbonated water, pipes are both larger and more numerous than where it is thickly covered, is further evidence in favour of the theory of the chemical origin of the pipes, whilst on the other hand it is in no way explained by the mechanical theory.

With all due respect therefore to the opinions of other geologists who have written on the subject, I must state my doubt of there being proof of any unevenly eroded surface of the Chalk (that is to say such a surface worn down before the deposition of the succeeding beds) below the older Tertiary formations in England, whether the Chalk is overlain by the Thanet Beds, or in their absence by the Woolwich and Reading Beds: an uneven surface is not needfully an eroded one.

Although there seems to be no proof of unconformity between the Thanet Beds and the Chalk, yet I am far from saying that there is no such unconformity; palæontologically there is a great break, and this would lead us to expect a stratigraphical irregularity also. Indeed it seems that the highest part of the Upper Chalk is absent in many parts of the London Basin; but the planing-down of the Chalk by which this has been brought about was of so even and gradual a kind that it cannot be seen, even in the longest junction-section: it is only inferred from the comparison of Chalk-tracts that are miles apart.

It may be well here to repeat the following remarks of PROF. PRESTWICH:—"In viewing the London Tertiaries as a group,

\* *Phil. Mag.*, ser. 3, vol. ix. p. 360. (1836.)

† *Quart. Journ. Geol. Soc.*, vol. i. p. 300, vol. x. p. 231, and vol. xi. p. 62. (1845-1855.)

‡ *Phil. Mag.*, ser. 3, vol. xv. p. 257. (1839.)

§ *Rep. Brit. Assoc. for 1839*, p. 276.

|| *Quart. Journ. Geol. Soc.*, vol. xi. p. 64, where the question is fully gone into. (1855.)

and comparing them, as usual, directly with the underlying Chalk, it is to be observed that we are not comparing like terms of the two periods. That a great and essential difference existed between these periods must be admitted, but it is a question how far that difference is widened by the comparison being instituted between the deep and open sea deposits of the Chalk, and the littoral, shallow-sea, and fluviatile deposits of the Tertiary period, instead of between strata deposited under like conditions during those two periods. . . . Where more shallow-water conditions again prevailed during the later Cretaceous periods, as at the time of the deposition of the *Calcaire pisolithique*, the fauna which then flourished presents forms so closely resembling those of the overlying Tertiary strata, &c. . . . I mention these facts, not as attempting to ignore the value of the distinction drawn between the Cretaceous and Tertiary periods, but for the purpose of suggesting whether this distinction is so extreme as we have considered it."\*

I believe that in no place where the Thanet Beds are present is the top of the Chalk riddled with those singular holes (that have been referred, though probably wrongly, to the action of boring mollusks), sometimes to be seen where the Reading Beds come next the Chalk (see p. 125).

#### *Fossils.*

The fossils of the Thanet Beds in East Kent are distinctly marine, but in the western part of Kent and in Surrey the sand is practically unfossiliferous; so much so at least that the only fossils I have seen in working over the district were the two from Croydon. Moreover all the recorded occurrences of fossils can be counted on the fingers, being as follows:—

*Charlton and Woolwich.* Impressions and casts of shells (*Cyprina*, *Pholadomya*), cast of fish vertebra. ? Remains of oyster-shells immediately above the Chalk.

*Croydon.* Tooth of *Lamna*, and a broken shell. PROF. PRESTWICH writes to me that he saw, in the collection of the late MR. J. FLOWER, casts of *Cardium*, of *Pectunculus*, and of *Cucullæa*, from here.

*Erith.* Casts of bivalve shells.

*Lewisham.* Two casts of *Cyprina*.

Few therefore though they are the fossils are here also distinctly marine. Moreover, in conducting an excursion of the Geologists' Association in 1887, my colleague, MR. J. G. GOODCHILD found, at Plumstead Station, a hardened mass which yielded the following shells:—

<i>Cardium semigranulatum.</i>	<i>Modiola</i> , twisted, like <i>M. Nysti</i> .
<i>Cucullæa.</i>	<i>Ostrea</i> .†
<i>Cyprina Morrisii</i> ,	<i>Pectunculus</i> .
<i>Cytherea</i> .†	

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 443. (1854.) Reproduced in his Presidential Address. *Ibid.*, vol. xxvii. (1871.)

† Added on the authority of MR. G. F. HARRIS. *Proc. Geol. Assoc.*, vol. x., no. 2, p. 47. (1887.)

## DETAILS.

*Between the Valleys of the Mole and of the Wandle.*

The point where this formation thins out is uncertain; but when the Survey was made I could not see it west of Ashstead. Many years after, however, MR. S. B. J. SKERTOHLY and MR. H. H. FRENCH found that it extended further west than was shown on the map,\* and the latter gentleman has shown me the sections close to Leatherhead, which clearly prove the presence of Thanet Sand. I hope that he will carry out his intention of trying to trace it still further westward, across the valley of the Mole.

From Ashstead the Thanet Sand runs, with a general north-easterly trend, by Epsom to Ewell; and thence almost due east, by Cheam, Sutton, Carshalton, and Beddington, to Croydon. In its range eastward it gradually thickens, as a rule, very slowly at first, being but a few feet thick in Ashstead Park, where the "bottom-bed" of the Woolwich and Reading Beds may be seen within a very short distance of the Chalk.

By the footpath from Leatherhead to Lower Ashstead, and about half-way between those places, an old chalk-pit, on the southern side, showed some of the green-coated flints above the Chalk at one place, whilst close by eastward, and on the other side of the path the following section was to be seen:—

Mixture of Gravel, etc., resting irregularly on the bed below.

Reading Beds. Green-grey sandy clay.

Firm light-coloured Thanet Sand; some feet.

It was shown (in 1859) in a lane on the eastern side of the turnpike-road just west of Ashstead, where it seemed to be very thin.

At Epsom it is much hidden by gravel, but is well shown in the cutting on the London Brighton and South Coast Railway just out of the town (on the N.E.), where it is capped by the "bottom-bed" of the overlying Series. At the kiln close by, between the railway and the road, the beds have been sunk through to the Chalk, and according to the information given me, the Thanet Sand was found to be 15 feet thick.

At the kiln on the western side of the road between Epsom and Ewell I saw below the Reading Beds (see p. 127) more than 10 feet of Thanet Sand, the Chalk not being then reached. It may be seen, under like circumstances, at Nonesuch Kiln, just east of Ewell, in the railway-cutting to the south-east, and at Howell Hill still further in the same direction.

Just east of Cheam Church there is a pit in this sand, and in the lower part of the garden of the house at the corner of the road just N.W. of Sutton Church the Chalk was reached after passing through 15 feet of it, and (in 1859) I saw the sand underneath gravel in a small pit about half a mile N.E. of Sutton Railway Station.

At Carshalton no section in this formation was seen, and eastward of that village its junction with the Chalk is in great measure hidden by the gravel of the Wandle, but the Tertiary beds must occur beneath the gravel a very short distance to the north of its boundary-line.

This formation, the outcrop of which up to this neighbourhood forms but a narrow tract between the other Eocene beds and the Chalk, now gets much thicker, takes up a larger space at the surface, and runs out in spurs with well marked features, and for the most part not capped by the Woolwich Beds. It may be well seen in the road-cuttings at Beddington, which have the usual picturesque look of the deep-cut lanes of a Thanet Sand country, and in the railway-cutting south of the village.

\* *Geol. Mag.*, dec. iii., vol. iii. pp. 335, 336. (1886.)

Another spur spreads over Waddon Court to the southern side of the railway; and a third, with a small capping of gravel and of the Woolwich Beds forms Duppas Hill, on the western side of Croydon, and reaches to within a quarter of a mile of Hayling House, on the hill just to the east, where the sand is again hidden by gravel.

*Between the Valleys of the Wandle and of the Cray, and down the Left Side of the latter, to Bexley.*

On the eastern side of the Croydon valley this formation and the Woolwich Beds together form one well-marked escarpment. The junction of the former with the Chalk is well shown in the railway-cutting on the northern side of Combe Lane, and was so in a large pit about a quarter of a mile further east. At the former place the junction is rather irregular, and shows a slight dip to the north; at the latter it was even and regular, and the upper part of the sand had a pinkish tint. At both there are flints at the base of the sand, which in this neighbourhood is from 30 to 50 feet thick.

When visiting the pit with me (in 1870) MR. DOWKER found a broken shell (undeterminable) in the sand, and the late MR. COOPER, of Croydon, showed me a tooth of *Lamna* from the same. The section is now hidden.

The railway-cutting just to the east laid open great part of the Thanet Sand, showing the junction with the Woolwich Beds above (see pp. 130, 131).

Eastward from this there are no sections of any size for some distance. The Thanet Sand crops out along the flank of the low ridge to Lord Eldon's Park at Shirley, and then rises southward to the spur near Selsdon, whence it again falls slowly N.N.E. along the well-marked escarpment above Addington and Wickham Breaux, until near the latter place it is in the bottom of the valley (of the Ravensbourne) and mostly covered by gravel. Then it rises south-eastward for about two miles, reaching its highest point in this neighbourhood at Keston, whence it again falls slightly to Farnborough, and then runs northward, with a broader outcrop, along the left side of the valley of the Cray, the junction with the Chalk being hidden from Orpington northward towards Bexley by the Brickearth and Gravel of that valley, except at one place, where the base-bed is shown above the Chalk (half a mile S.W. of St. Paul's Cray church). There are occasional small pits and road-side sections, the only noteworthy sections being a pit at Poverish and the neighbouring cutting (on the London Chatham and Dover Railway) at St. Mary's Cray Station, in both of which the sand is capped by the bottom-bed of the Woolwich series (see p. 137).

At Bexley the Valley Gravel wholly covers the Thanet Sand on the western side of the Cray, and the latter most likely occurs in the bottom of the valley here.

*Between the Valleys of the Cray and of the Darent.*

From Bexley the Thanet Sand spreads irregularly southward by Joydens (or Jordens?) Wood and Hackendean to Crocken Hill, and seems to be faulted between the last place and St. Paul's Cray.

The mass that stretches southward from St. Paul's Cray to Petting Grove is bounded on the north-east by one of these faults, and indeed, but for it, would be cut off from the rest as an outlier.

In the new graveyard at Bexley, east of the church, the sand is found in the graves at the higher part, and on the road to the south it is shown to be capped by the Woolwich Beds.

East of St. Mary's Cray is a long and for the greater part deep cutting in the Thanet Sand, almost divided in the middle, where there is a hollow of loam, of which there is also a little at the western end. On the western side of the bridge nearest to the Cray there is (on the south) about a foot of red, orange-coloured and yellow sand at top; on the eastern side there is pebble-gravel, two or three feet thick, capped at one spot by a little sand, and on the opposite side of the cutting there is as much as six feet of pebbles at the highest parts; this looks as if a trace of the Woolwich or of the Blackheath Beds had been left here. About 130 yards west of this bridge a shaft has been sunk through 12 or 15 feet of the sand into chalk. At the eastern part of the cutting there is a long hollow in the sand, filled with clay, loam and sand with pebbles, bottomed by an irregular bed of pebbles with a few flints, and at one place containing brown clay, with shells, and blackish clay, both derived from the Woolwich Beds.

There are deep cuttings in the Thanet Sand along the road east and west of Kevingtoun. On the former side there is at one part, and that not the highest, a little brown clay with shells above the sand; this drifting of masses of the shell-beds of the Woolwich Series is not uncommon hereabouts.

The cuttings on the London Chatham and Dover Railway from Tile Kiln Wood to Swanley Station show the sand, mostly with a thin capping of the Woolwich Beds, and there are many sections along the roads and lanes.

Mr. T. V. HOLMES told me, in 1883, that he had been present at the descent of two dry wells in Joyden's Wood, which, though partly filled up, gave the following sections:—

1. Within the Ancient Camp. Thanet Sand 60 feet. Chalk 43½.
2. East of „ „ „ „ „ 25½ „ „ 70½.

The same observer adds that in the shaft of a Denehole at Cavey Spring, in the north-western corner of this wood, 46½ feet of Thanet Sand was found, above the Chalk.

East of Bexley the Thanet Sand is for the most part capped by the gravel that forms the plain of Dartford Heath. Along the southern edge of this tract, from Honeywood to Oakfield Lodge (overlooking the valley of the Darent), the boundary of both deposits seems about the same, but the lower and more clayey part of the sand crops out from below the gravel in places along the ridge; northwards, towards Dartford Hill, the junction of the Thanet Sand and the Chalk is altogether hidden by the gravel and brickearth.

At Dartford Heath Brickyard (by Heath Farm) there is brown brickearth, 12 feet or more thick, clayey at top; but the rest more sandy, with layers of sand and finely bedded. At the bottom of this is mostly a layer of gravel, which rises to the surface and thickens westward, and then light-coloured Thanet Sand, of which I was told that about 40 feet had been sunk through in a well before reaching the Chalk, and that it had flints at the base.

At Wantsunt Farm, south of Crayford, there were two junction-sections of the Thanet Sand and the Chalk, with the usual green-coated flints at the base of the former.

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On the Wilmington ridge are two outliers, the western of which is barely divided from the main mass and is free from Drift, whilst the other (at the village) is in great part hidden by brickearth.

*Up the Valley of the Thames, between the Cray and the Ravensbourne.*

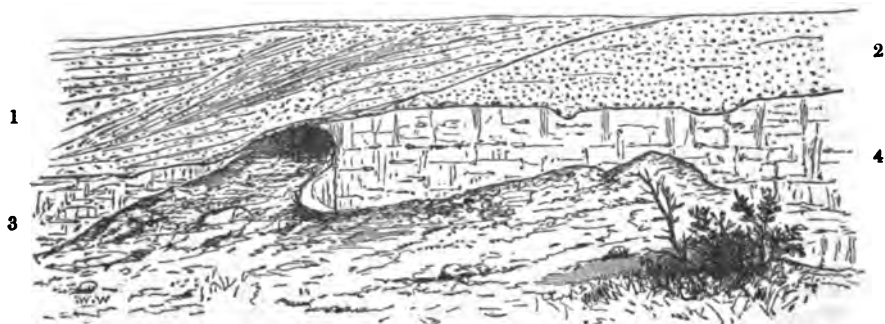
From Crayford the boundary-line runs north to Erith, and then north-westward for about a mile, but it is much hidden by the thick deposit of Brick-earth, which abuts against the escarpment.

From Erith the outcrop of the Thanet Sand turns westward, along the line of the Thames Valley, to Greenwich, and is bounded on the north, as far as Plumstead, by a fault with a considerable downthrow in that direction, bringing the Blackheath Beds against the sand, except at the small inlying exposure of the Chalk between Plumstead and East Wickham. Along this course small sections are plentiful, and some show the junction with the Woolwich Beds (see pp. 142-145, 147-149).

Between Greenwich and Deptford the Thanet Sand is cut back southward, for a mile or more, along the valley of the Ravensbourne, and north-westward it is wholly hidden by the Gravel and Alluvium of the Thames; but by means of borings it can be traced under the dreary district between Deptford and Rotherhithe, which, although actually flat, is geologically a denuded arch or dome.

At the southern end of the western face of the great brickearth-pit of Crayford (north-east of the village) there is Thanet Sand above Chalk, and the chalk-pit belonging to the brickyard gives a good section of the junction and of the cutting off of the sand eastward by the brickearth. The southern face is the best, or at least was so at the time when I made the sketch, Fig. 6.\* The northern face was much the same, but showed very little Thanet Sand, and the western face is in Chalk and Thanet Sand with a hollow of Drift.

*Figure 6. Southern Face of the Chalk Pit west of the Crayford Brickyard (1867).*



1. Brown sandy brickearth.
2. Thanet Sand, with green-coated flints at the bottom. These and a few inches of the sand continued along the top of the Chalk over the hole or shallow cave.
3. Rubbly chalk, partly hardened at the junction on the east of the cave.
4. Chalk with flints.

\* The same view as Fig. 23 of Mr. A. TYLOR's paper, *Quart. Journ. Geol. Soc.*, vol. xxv. p. 91. (1869.)

In the chalk-pit at the southern end of the western face of the great Erith brickyard (south of the town) there was another good junction-section, which was as below at the time of my visit (June 1867).<sup>\*</sup> This section is now hidden, the yard having been abandoned:—

Brown brickearth, gravelly at top and at bottom, 15 to 20 feet (at the eastern side of the pit cutting down some 12 feet into the Chalk).

Thanet Sand, 15 to 20 feet; the lower part darker (greenish) but not very clayey; with green-coated flints at the bottom, many very large, in very green earth (5 or 6 inches) between which and the Chalk there was sometimes a 3-inch layer of brown ironstone, the Chalk below being then very hard at top and hardened for a few inches down. The Thanet Sand rested evenly on the Chalk, except for a long shallow hollow (of about two feet) cut through on both the western and eastern sides.

Chalk with flints, a marked tabular layer of flint about 15 feet down.

The Thanet Sand was also shown, below the brickearth and gravel, in the long westerly cutting from the chalk-pit, and in the still longer one (to the higher part of the brickyard) just north.

The layer of ironstone on the Chalk occurs again at the second bridge south of the railway-station, and the sand occurs below gravel in the cutting.

In the large sand-pit at the Station, a section of which is given at p. 142, on the western side of the railway a small cutting touches Chalk, a little more than a foot below the floor of the pit, and shows the usual base-bed. At the north-western corner of the pit, where it is cut across a hollow, there was some irregular gravel over the sand. The compactness of the sand and the firmness with which it stands were well marked at the south-eastern face. East of the railway the chalk is touched, the junction having a slight south-westerly dip, and showing in parts some dark green clay and ironstone next the Chalk, as at the brickyard.

A pit at the northern edge of Belvidere Park, and about half a mile south-eastward of the railway-station, is in the following beds:—

Loamy wash, and at one part a little of the base-bed of the Thanet Sand.

Chalk with flints. About 12 feet down an almost continuous layer of flint, as at Erith and Crayford.

A pit at the eastern edge of Old Park Wood, and opposite the Wickham Lane Brickyard shows Thanet Sand, with a bed of green-coated flints at the base, a foot thick, and resting evenly on Chalk with flints.

At Woolwich the Thanet Sand is cut off by the alluvium of the Thames, or by the river itself, but in the western part of the town the Chalk crops out, and the junction runs thence S.S.W. for about four miles, being hidden however in the neighbourhood of Greenwich by the gravel of the Thames. What with the cuttings of roads and of railways and pits there is no want of evidence in this range.

The large pit south of the dockyard gives one of the great sections of the district, and is perhaps as well known to geologists as any place near London, showing as it does almost the whole of the Lower London Tertiaries. Here the Thanet Sand is cut through from top to bottom (see p. 148).

One of the best and largest sections of the junction with the Chalk is close by, in the great pit east of Charlton Railway Station, which shows a very long face of Thanet Sand. It was in this pit that the mineral allophane was found by PROF. MORRIS, at and a little below the junction.† In the lower (eastern) part the Thanet Sand is capped by a Valley Drift of sand and gravel, but at the highest part by the Woolwich Beds (see p. 147, where the section is described in detail).

The junction of the Thanet Sand and the Chalk is again shown in the railway-cutting to the north of the Kidbrooke Tunnel, where two small outliers of the former are artificially cut off.

<sup>\*</sup> MR. TYLOR's section (*Quart. Journ. Geol. Soc.*, vol. xxv. fig. 18, p. 86) is from this pit.

† *Quart. Journ. Geol. Soc.*, vol. xiii. p. 13. (1857.)



The cutting at the northern end of the tunnel is in Thanet Sand, capped at the highest part (on the eastern side) by rather coarse sand with green grains (the bottom-bed of the Woolwich Series).

The railway-cutting on the Greenwich line, westward of Westcombe Park Station, is in Thanet Sand, partly capped by gravel and sand of the River Drift.

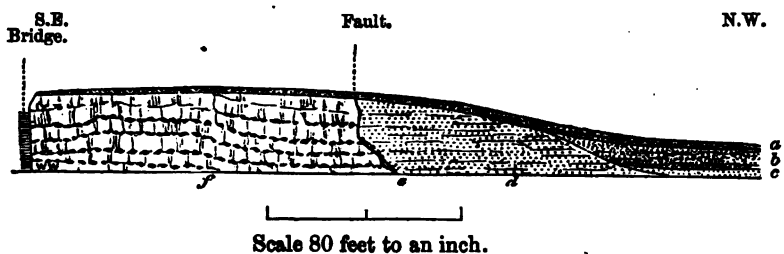
Beyond this there is no section worth speaking of before getting to a very large old and in great part overgrown pit (in private grounds) on the southern side of the high road from Deptford to Blackheath, and about half a mile south of the Greenwich Railway Station, where the whole thickness of the Thanet Sand is shown (see p. 151).

The Thanet Sand crops out along the bottom of the valley between Lewisham Junction and Blackheath Stations, and is also shown sometimes in the railway-cutting beyond the latter.

The most northerly of the great pits at Loam Pit Hill again lays open the whole thickness of the Thanet Sand (see p. 154), and this formation also occurs in the new railway-cuttings a little north-westward (see p. 155).

The cutting on the same railway (North Kent) just northward of St. John's Station passes through a faulted junction of the Thanet Beds and the Chalk, as shown in Fig. 7 which was taken on the western side.

Figure 7. Cutting on the North Kent Railway, St. John's Station.



- |                 |   |   |   |
|-----------------|---|---|---|
| River<br>Drift. | { | a. Soil.  | e. Layer of green coated flints, half-way up the fault.                               |
|                 |   | b. Brickearth, with a little sand above or in it. | f. Chalk, somewhat rubbly, but with flints in layers, three of which are well marked. |
|                 |   | c. Sand.  |   |
|                 |   | d. Thanet Sand.                                   |   |

I believe that this abrupt junction is caused by a fault rather than by piping, because the Thanet Sand shows signs of flat bedding, because the base-bed does not occur all the way up, and because it is in line with the Greenwich fault. The other side of the cutting was not clear, but the junction was more vertical.

Southwards the cutting is in Chalk only; northwards in the superficial deposits and the Woolwich Beds (see p. 156).

### *Inliers, West Kent.*

#### *Bromley.*

The section of the well at the waterworks in the bottom of the valley of the Ravensbourne, near the Shortlands Railway Station (see Well-sections), shows that the Thanet Sand next underlies the gravel there. This must be owing to a local uprise of the beds. As there are no other sections it is hard to say how far this inlier may extend, but most likely it is very small, and almost everywhere hidden by the gravel; the occurrence of the bottom-bed of the overlying series some way above the bottom of the valley at

Bromley Hill Wood (see p. 161) would seem to give evidence of a narrow outcrop east of the stream. Possibly the Thanet Sand may be bounded by a fault on the western side.

*Chiselhurst.*

The valley that runs through Sundridge, Camden and Bickley Parks, between Bromley and Chiselhurst, lays bare an outcrop of this formation and the Chalk, in the form of an inlier, that is to say, surrounded on all sides by a higher formation. This exposure of the Thanet Sand within the area of the overlying Woolwich Beds, and at so high a level, is owing to a slight upheaval of the beds, which has brought the lower formation within reach of the common forces of denudation. The outcrop extends from the north-western part of Sundridge Park, through Camden and Bickley Parks.

I was told by the steward of the estate that the house in the first of these parks is on white sand; and just south of the lodge on the road that divides this from Camden Park there was a section showing:—

Drift of brownish loam and sand, with flint-pebbles (partly in layers) 8 or 10 feet, sweeping down to the Chalk at the northern and lower end.  
Thanet Sand, dark bluish-grey and greenish-grey, clayey, with green-coated flints at bottom, 6 or 7 feet.  
Chalk.

The loam at the top seems to occur all along the inlier, masking the boundary-line. The sand has been dug at the fork of the roads to the north, just outside the park.

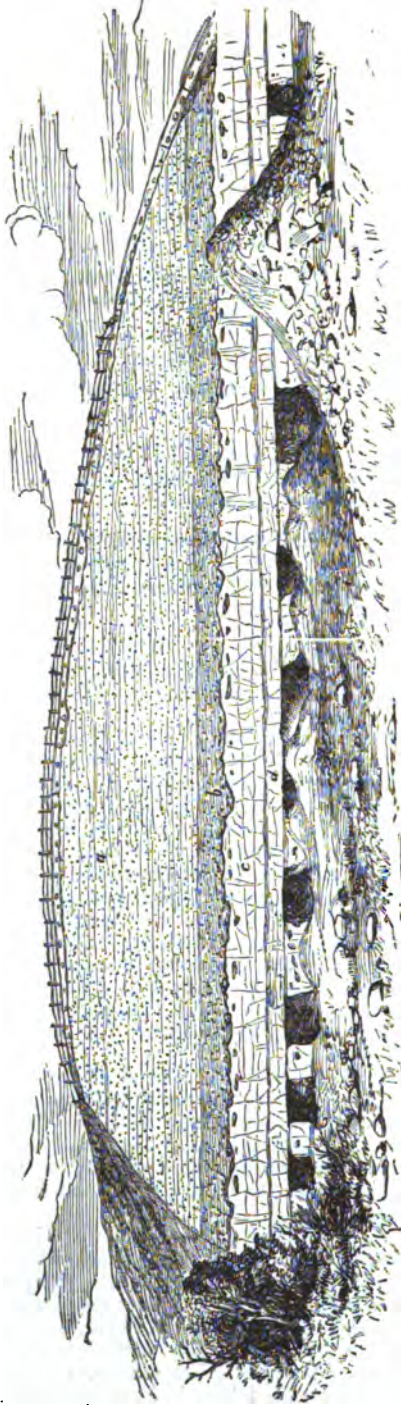
At about the centre of Camden Park and on the north-eastern side of the brook is a pit that has been worked for Chalk for very many years, by means of galleries driven in a long way underneath the Tertiary hill. There is, however, a clear section at the mouth of these, as in Fig. 8, in which I have taken some liberty with the actual view of the pit, in order to show the whole.

On the southern side of the road to Bromley, about three quarters of a mile westward from Chiselhurst Church, there is a set of sections in this formation. Near the stream is a large old pit showing 30 feet or more of the sand, which is of a very pale grey colour, the lower part darker and more clayey, and with green-coated flints at bottom. I believe that I found a small piece of allophane at the junction with the Chalk, which latter rock has layers of very large flints, sometimes as much as 18 inches thick, one being at or close to the top. The evenly bedded hard chalk that forms the *roof* of the galleries in the Camden Park pit occurs here also, and in great part formed the *floor* of that part of the pit that was being worked in 1866.

At the lime-kiln, higher up, I was told that the shaft was sunk through 43 feet of the sand (blackish and hard at the lower part) to the Chalk, into which the shaft is carried 20 feet further, when "stone" is touched. This, which is used as the floor of the galleries, is most likely the hard bed above noticed. A little way above is a pit showing 25 feet of sand, so that the total thickness here would be about 70 feet, the bottom of the pit being somewhat higher than the top of the shaft.

In the wood, between the lime-kiln and the large old pit, a long triangular steep-sided chasm has been cut in the sand. At the pointed eastern end, about 10 feet deep, a stream falls into it and then flows with a sharp slope to the western end (the base of the triangle, and about 40 feet deep) where the sides are very steep and where it runs into a cavern in the Chalk, which rock is just shown at that end. I do not know whether this swallow-hole is natural or not, but I expect not, for the wood is full of holes, some of which are old pits, and others may have been caused by the falling in of the ground from undermining, though some may perhaps be true swallow-holes.

Figure 8. *Diagram-Section of the Chalk Pit in Camden Park, Chislehurst (1871).*



Loamy and gravelly soil.

Thanet { *a.* Clayey bedded sand, somewhat darker than usual, about 30 feet.

Sand. {

*b.* Base bed,  $5\frac{1}{2}$  feet, clayey greenish and with green-coated flints as usual; the lower half very dark. Many very small pipes in the chalk.

*c.* Chalk with flints, bedded, showing a dip of about  $1^{\circ}$  N.W. along the face. At a depth of 7 or 8 feet more or less hard (*d*) for about 40 inches down, the upper part of this marked bed being very hard and rather darker, and the bottom forming the even roof of the galleries. (*e*) The bed next below is also hard at top.



from the gravel of the hill-top through the Thanet Sand into the Chalk. A like section was noted by Mr. T. V. HOLMES (in 1882), in going down one of the Deneholes in Hangman's Wood, which passed through 5 feet of gravel, 53 of Thanet Sand, and 22 of Chalk: others of these holes of course show slight variations from these figures.

The junction with the Chalk was shown just above the brickyard north of Little Thurrock, on the western side of the road to the Rectory.

Mr. H. W. BRISTOW has made the following notes:—"North-east of the church this junction may be well seen in two pits, one at the northern end of a small wood, the other close by on the north. The top of the Chalk is slightly undulating, but not furrowed into pot-holes. The Chalk contains layers of flints, but not in great number, and the flints are large and irregular in shape, one layer being however more tabular and sometimes six inches thick. The beds of chalk are rather thin, and have the joints stained ochreous brown. At the junction there is a bed of flints, six inches or more thick, for the most part black or grey, with ferruginous stains, but with now and then a white flint." Whether the mound of Thanet Sand north-east of Little Thurrock is an outlier, or whether it joins on to the main mass on the east, under the alluvium, is doubtful.

"There are good sections of the sand in the lane south of Chadwell Place, and also south of Chadwell."

#### Outliers.

The conical mound east of Purfleet, which forms a marked object at some distance, is an outlier of Thanet Sand, and a small patch has been artificially separated in the great pit, in which the section is as below:—

Gravelly soil or wash.

Thanet Sand, many feet, the lower part with the pinkish tinge that has been noticed at Lewisham, &c. At the bottom green-coated flints in green sand.

Chalk with flints. At the top a bed of large whitey-brown flints, some of which have been broken and rejoined, as in East Kent. About 15 feet down a continuous layer of flint.

A small outlier at Mitchell's Shaw, S.E. of Aveley, seems to be barely separated from the main mass. It is hidden by gravel, except at its northern edge.

A larger mass makes a well-marked feature along the hill for more than a mile from above West Thurrock to beyond Belmont Castle. At a large old pit south-east of the latter place the section extends from the gravel, which there covers the hill-top, through the sand to the Chalk, and there is a good junction-section in the large quarry north-west of Grays Church, where many of the green-coated flints at the base of the Thanet Sand are large; at one place there is a little black earth at the junction with the Chalk, and in parts there are whitey-brown flints below the green ones. Some feet down in the Chalk there is here, as at Purfleet, a marked flint-bed. A fine autotype print, from a photograph of a view "in the South Central Chalk-pit," has been given as a Plate, to accompany an account of an excursion here. It shows a large pipe in the Chalk.\*

In the large pit southward of Stifford Church and north of the above, there is a capping of Gravel and Thanet Sand over the Chalk, at the south-western corner.

At the north-western corner of the Chalk-pit north of Grays Railway Station there was a thin irregular patch of the base bed (cut off by Drift sand and gravel), which seems to reach to the eastern edge of the adjoining and still larger pit on the west, where there are pipes of the base-bed, with gravel and chalk-rubble (1872).

\* *Trans. Epping Forest Nat. Field Club*, vol. ii., pt. 5, *Journ. of Proc.*, p. xv. (1881.)

*Outliers between the Valleys of the Darent and of the Medway.*

Thanet Sand crops out between the gravel and the Chalk at the eastern end of Dartford, on the flank of the hill. The junction with the Chalk was seen in a small cut on the northern side of the high road, opposite the lane running southward, whilst the road-cutting just above shows coarse gravel over the sand. The large pit nearly between the road and the railway is in gravel, over Thanet Sand, over Chalk-with-flints. All but the western boundary of this patch is hidden by the gravel.

At Sandhill, about a mile north-east of Dartford Church, a little Thanet Sand is again to be seen, here again almost wholly covered by the gravel.

On the south of the Watling Street about two miles from Dartford is another very small patch.

*Swanscombe.*

This is the largest Tertiary outlier south of the Thames, and consists of three masses of London Clay (with a slight capping of pebble-gravel at the highest part of the largest) two of the Woolwich Beds (see p. 17), (the Oldhaven Beds being absent), and Thanet Sand. Although partly beyond our district it is best to describe the whole together. Its boundary is of a more or less winding character, except on the south, where from the northerly dip and the less undulating surface it is more even.

On the north the Thanet Sand is cut off by the high terrace of Valley Gravel through which the North Kent Railway passes.

Sand may be seen along the roads near Weston Cross, Stone Wood, Lane End, Green Street Green, Westwood, and Betsam, and many shafts have been sunk through it to get to the chalk below. The base-bed is also to be seen in parts, and at the eastern part of Darent Wood its junction with the Chalk.

At the Westwood brickyard there is light-brown or buff loam or fine clayey sand capped by about five feet of dark brown brickearth.

It is possible that the dry gravel-bottomed valley of Green Street Green, may cut this outlier into two. On the western side of this valley the sand forms a narrow capping to the hill, from St. Margaret's northward to beyond Darent, and there is a good section of the junction with the Chalk, here slightly uneven, a few yards west of the cross roads just above the latter place. Southward the Thanet Sand takes up a broader tract, reaching up to the London Chatham and Dover Railway. In the long and deep cutting through the Chalk-with-flints on this line, there are, on the east of the nine-mile-post, a few small pipes and patches of the base-bed, and before getting to the next quarter-mile-post a few feet of it caps the Chalk for some way.

*Perry Street.*

From Springhead a fair-sized outlier reaches eastward to Newhouse and thence southward to the Watling Street. At Perry Street there was a long section (in an old brickyard ?) showing brown Brickearth with a little gravel at the bottom, five or six feet thick, over buff clayey Thanet Sand, like the upper part of that in the Gravesend brickyard (see p. 120), dug into for about eight feet.

PROF. HUGHES has noted that "the wells on the northern side of the main street of the village seem to be through about 12 feet of loam and gravel to the Chalk, whilst those on the southern side show the junction of the Thanet Sand and the Chalk at about 12 or 15 feet."

The sand and the base-bed are to be seen on most of the roads. On that a few yards north of Dundle Farm the following beds are shown :—

- { Brown loam (rainwash ?)
  - { Buff sand with streaks and patches of calcareous matter, 3 feet at most.
  - { Irregular layer of gravel, resting unevenly on—
- Grey Thanet Sand.

The hole dug for a cesspool at the house next on the south to Gravesend Cemetery showed—

	FEET.
Made ground, &c. - - - - -	about 1
{ Light-brown clayey sand (brickearth), with a few pebbles -	7
{ Irregular gravel of pebbles and flints, some with a thin calcareous coating; with an included mass of the base-bed - - - - -	2 to 2½
Thanet base-bed; green loam, iron-stained, flints at the base	3 to 3½
Total to Chalk -	13½

Between Northfleet and Gravesend are three small thin outliers. One of these is cut through by the railway just north of Perry Street; another is crossed by the London Road about half a mile eastward of Northfleet Church, a long and even junction of the base-bed with the Chalk being shown by the large pits on either side of the road.

The third is just eastward. A few chains south of the church, on the high road about half a mile west from Gravesend station, is a long section of grey clayey Thanet Sand: There has been a brickyard here, and there are remains of old pits.

#### *Gravesend.*

The southern part of this town is on a well-marked outlier, apparently in a slight trough, with the beds dipping gently inwards both from the north and south.

In the brickyard on the southern side of the high road, half a mile westward of Mount Pleasant, there was (in 1862) a large squarish deep pit that gave the following section :—

Soil, with pebbles, 1 or 2 feet.

Thanet Sand, clayey throughout, 16 feet or more; the bottom 8 feet dark.

At top in one place fine wavy bedding; flints at the bottom. Even junction with—

Chalk with flints, about 30 feet.

The lowest part of the Thanet Beds is not used for brickmaking.

The sand is cut into on the northern side of the high road eastward, and the base-bed on the same road at the eastern end of the outlier. In the excavations for a house not far south of the railway-station the base-bed was again seen.

Just south of the above outlier, between the lanes to Northumberland Bottom and Singewell, is a small patch, the base-bed being shown in both of the lanes. At the eastern end of Chalk Street is another small sand-outlier.

#### *Main Mass between the Thames and the Medway.*

On the northern side of the "Hundred of Hoo" the Thanet Sand, dipping southwards, has an outcrop averaging about half a mile in breadth from the marshes of the Thames just east of Cooling to those south-west of Cliffe, but along this range I saw no section of the junction with the Chalk, which is in low ground throughout.

Westward the Thanet Sand borders the alluvium to Higham, then passes under it, and perhaps joins the Essex mass, though most likely the rise of the Chalk is continuous. About a mile and a half W.S.W. of that village however the sand is again brought up to the surface, by the northerly dip which there comes on. The

outcrop then runs a little south of east, until it passes out of our district.

I was told that in a well about 30 feet deep at the cottages ("Queens") near Lower Shorne Farm, Chalk was not touched, the lower part being in sand.

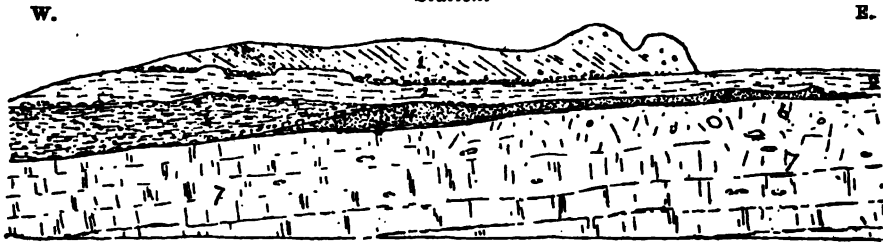
At the south of Green Farm the base-bed is shown in a chalk-pit. The junction is even, with a slight dip a little E. of N., and it shows a slight apparent unconformity, the base-bed being for the most part separated by about a foot of chalk from a well-marked layer of flints, which however it touches at one place.

On the road by the "Tumulus" (marked on the Ordnance Map) the sand may be seen, and the cutting along the road rather more than a quarter of a mile westward of Higham Station is in light-coloured Thanet Sand, with some irregular soft sandstone, which is mostly coloured light-brown by iron, and contains a few indistinct traces of vegetable remains.

In the railway-cutting at Higham Station a long even junction of the Thanet Sand and the Chalk is shown on the north-eastern side. The Chalk is at the surface at the highest part, but owing to the north-westerly dip (increasing from  $2^{\circ}$  to  $6^{\circ}$ ) the sand comes on as the ground slopes downwards, and the Chalk sinks below the level of the line before getting to the road-bridge. The grey base-bed is rather marly, drying so as to break up into cuboidal forms, and has the usual green-coated flints. Above the whole is a bed of loam, with flints and pebbles, which is covered on the east by spoil-heaps from the tunnel.

The accompanying figure (9) has been compiled by MR. GOODCHILD from drawings by PROF. HUGHES and by MR. I. L. ROBERTS; but unfortunately the western end has been omitted.

Figure 9. Section in the Cutting on the South Eastern Railway at Higham Station.



1. Spoil-heap, from the railway-tunnel; 10 feet at most.
2. Dark clay, with pieces of chalk and flints; 8 feet at most.
3. Light-coloured clay with sand (especially at the bottom), with small particles of chalk and flints; 4 feet at most.
4. Greenish sand, with a few small particles of chalk and very small rolled flints.
5. Layer of flints, at the base of the Thanet Sand. The greenish-grey loam of the base-bed comes on above this to the west.
6. Rubbly Chalk.
7. Chalk with a few large flints, not in regular layers.

The long and deep railway-cutting southward of Cliffe Rectory is in Thanet Sand, which was very wet at the bottom in 1881. At about the middle there were signs of a slight erosion, or gentle current-bedding, an upper bed of the sand filling slight hollows in a lower one, the infilling upper sand seeming sometimes to contain some broken-up pipe-clay. This occurrence was a new thing in the formation.

The next cutting eastward is small, and seemed to be in Thanet Sand. When there however, with an Excursion of the Geologists' Association, I was unable to examine it, merely passing through on a contractor's train.



## CHAPTER 9. LOWER LONDON TERTIARIES (WOOLWICH AND READING BEDS).

### GENERAL REMARKS.

This middle division of the Lower London Tertiaries is as constant in its presence as it is changeable in its structure. Where the Thanet Beds are absent it rests at once on the Chalk, but where that lower Series occurs the Woolwich and Reading Beds come between it and the still more local Oldhaven Beds, or when these last are absent between the Thanet Beds and the London Clay; the only exception being in the few places where the Oldhaven Beds have cut through to the Thanet Series, or in some cases to the Chalk.

In thickness this formation varies from about 15 feet in the far west, many miles beyond our district, to 80 or 90 feet in some of the deep wells under London, though the latter thickness has never been measured at the outcrop in the London Basin. Eastward from London it again thins, and northward too.

The plastic clays of this series were the cause of its being named "argile plastique" or "plastic clay series" by the older geologists, who included however the whole of the Lower London Tertiaries under that name. This is clearly a misnomer, for, not only is plasticity a character common to clays, but also the particular sort of clay meant (which is better described as mottled clay) is sometimes absent from these beds, and is often plentiful in others (as for instance the Wealden and the Bagshot Series). PROF. PRESTWICH therefore established the term "Woolwich and Reading Series," the two chief conditions of the formation being well shown at those places (see above, p. 93). In this Memoir either of those terms will be used separately ("Woolwich Beds," or "Reading Beds") for shortness, according as either condition occurs in the district described.

### *Structure.*

There are three distinct conditions of the Woolwich and Reading Beds, so different indeed that no one seeing each type independently would imagine them, from their lithological structure, to belong to the same formation; nor would their fossils help, in one case there being next to none, in another case all being of more or less estuarine character, and in the third marine forms occurring almost exclusively. It is almost wholly through the observations of PROF. PRESTWICH that the parallelism of the widely differing members of this Series has been clearly made out (see pp. 91-93).

1. In its most general state this formation consists of irregular alternations of clays and sands; the former of many and bright colours, mostly mottled and very plastic; the latter also of many colours, both coarse and fine, sometimes with flint pebbles and now and then hardened into sandstone or conglomerate; loam

also occurs. This, the unfossiliferous type (except for the occasional occurrence of leaves in laminated clay) is in itself ever varying; at one spot there may be hardly anything but clay at another only sand, and at a third both may be in equal quantity. PROF. PRESTWICH has found that the mottled clays contain gelatinous silica.\*

This series of mottled clay and sand (in describing which the term "Reading Beds" will be used) occurs throughout the whole of the Hampshire Basin, except in the outlier at Newhaven. In the London Basin it is found all along the northern outcrop, and on the western part of the southern outcrop (from Berkshire, through North Hampshire and the greater part of Surrey), and now and then mottled clay is interbedded with the shelly clays further east, in which latter case the compound term "Woolwich and Reading Beds" is specially fitting.

2. In the eastern border of Surrey, in West Kent, in the border of East Kent, and partly in South Essex, we find, with the light-coloured sands, finely-bedded grey clay, mostly crowded with estuarine shells, and often with oyster-shells compacted into rock. Above this there is often (on the south-east of London) a fairly thick bed consisting of thin alternations of sand and clay, or loam; at the base of the shelly clays there is often a bed of imperfect lignite and lower down sometimes a pebble-bed.

As usual with deposits of this sort the species of fossils are few, but the number of individuals in some cases is very large. They occur occasionally in more sandy beds as well as in clay.

3. With the sand of East Kent, which contains marine shells, we have but little to do. It forms probably the lower part of the formation (except for the bottom-bed) and does not occur in our district, in a fossiliferous state, though probably represented by the unfossiliferous sand that overlies the bottom-bed in our south-eastern tract.

*Bottom-Bed.*—One part of the formation is fairly constant, but yet partakes somewhat of the varying character of the rest. Where it rests on the Thanet Beds this lowest member of the Woolwich and Reading Series is a green or greenish-grey sand, more or less clayey, with flint-pebbles, and here and there with oyster-shells. Where however it rests on the Chalk it is usually of a more clayey character, the flints at its base are angular and green-coated, instead of being in the state of perfectly rolled pebbles; as before there are sometimes oyster-shells in the green-sand, and besides there are (somewhat rarely) casts and impressions of other shells in the accompanying roughly laminated grey clays (with green grains). Such fossils however have been found chiefly westward of our district.

The difference in the condition of the flints in the two cases is just what one would expect: in the latter they have been got direct from the underlying chalk, whilst in the former they must

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\* *Quart. Journ. Geol. Soc.*, vol. x. p. 123. (1854.)

have been carried some distance, and therefore worn. There are however exceptional cases of the pebbly condition on the Chalk.

The well-known "Hertfordshire pudding-stone," of which so many blocks occur in Hertfordshire and in the neighbouring counties, seems to be a greywether-sandstone more or less crowded with flint-pebbles, and to result from the hardening of sandy pebble-beds in this formation. It is in our district alone that it has been found in place (see p. 200) being otherwise known only from the masses that occur either lying on the surface, or embedded in brick-earth.

MR. J. A. PHILLIPS has described this rock as "a conglomerate of flint pebbles united by a concrete consisting of fragments of transparent quartz and greyish flint held together by a flinty cement. In this concrete the quartz is considerably in excess of the flint, and sometimes contains fluid-cavities. Its fragments are all angular, and vary in diameter from  $\frac{1}{8}$  to  $\frac{1}{16}$  inch."\*

So compacted has this conglomerate become that the joint-planes that have been developed in it cut evenly through pebble and matrix alike, in very many of the blocks.

Some analyses of earths from this formation are given in a later chapter.

*Junction with the beds below.*

Although sections do not show any unconformity between this formation and the Chalk, yet there may be some unconformity, so gradual that it can be inferred only by the comparison of a series of distant sections. However, although the Reading Beds may rest on different beds of the Chalk at different places, there were no means of proving such to be the case in this district until quite lately, when the collecting of fossils from various chalk-pits in the neighbourhood of Maidenhead, by MR. RHODES, led MR. JUKES-BROWNE to infer that a higher bed of Chalk came in below the Reading Beds south-eastward, in that part (see p. 77). That there are local irregularities in the junction of these formations is well known; but these are now held to be owing to causes that have come into action after the deposition of the Reading Beds. I refer of course to the "pipes" of these beds that are so common in the Chalk, and which have been noticed in describing the Thanet Beds (see p. 107).

In the smaller outliers, where the Chalk is more thinly covered, and therefore less protected from the chemical action of carbonated water, pipes are both larger and more numerous; many of the smallest outliers being indeed nothing but large pipes.

The sinking of the beds into the pipes is sometimes gradual and sometimes rather sudden. I have heard of hollows being formed in fields, in parts where the surface of the ground was even the day before. Some pipes may at one time have been swallow-holes.

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\* *Quart. Journ. Geol. Soc.*, vol. xxxvii. p. 18. (1881.)

The Chalk immediately underlying the Reading Beds has been in some places drilled to a depth of a foot or more, and the network of tubular cavities thus formed is filled with the clayey greensand of the bottom-bed.

It has been suggested, by MR. W. H. HUDLESTON, that these holes have been formed by "the roots of marine plants, which, having no loose stones to cling to, must have either forced their supports into the little chinks of the sea bottom, or be [been] washed away."\* The holes in question are certainly not like those made by boring molluscs, to which they were at first referred, being very irregular.

Where this series rests on the Thanet Beds, instead of on the Chalk, the junction is often irregular, masses of the pebbly greensand of the bottom-bed scooping down into the underlying sand or lying very unevenly on it. In the most eastern part of Kent however, where the marked bottom-bed is sometimes absent, there is a passage between the two formations.

The boundary-line and the line of outcrop of the Woolwich and Reading Beds are for the most part of a very winding character, owing to irregular denudation.

"*Swallow-holes*," that is, caverns which swallow up streams that run into them, are common. They are formed by streams which, rising in the higher ground, flow down the escarpment of the Tertiary beds, until they reach the more pervious and jointed Chalk, into which they sink, or until they come within a short distance of that rock, when they work their way into it through the few feet of the softer overlying beds. In the course of time, through the chemical action of the carbonic acid in the water and the mechanical action of the water itself, funnel-shaped basins are worn in the Chalk and the beds above, the operation being made more easy by any pre-existing fissures. These hollows are often thickly overgrown with vegetation. The streams may sometimes be seen running through them, though sometimes they merely flow into a small pool, the level of the water in which remains the same, notwithstanding the constant flow.

These swallow-holes mostly occur at or near the junction of the Reading Beds and the Chalk, and they are therefore of much use in drawing the line between these formations, especially where there are no sections. They sometimes occur, however, at a distance from the Tertiary beds, and sometimes well within their boundary; both these conditions may be seen in the Mims Valley (see p. 203).

#### SOUTHERN OUTCROP.

##### *Between the Mole and the Wandle.*

Owing to the fairly-marked dip the outcrop is, for the most part, comparatively narrow, and without marked feature, and the boundary-line follows closely on that of the Thanet Sand.

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\* *Proc. Geol. Assoc*, vol. iv., no. 8, p. 521. (1876.)

When the Geological Survey was made, no section of the Reading Beds was seen from Ashstead to Leatherhead, and MR. H. H. FRENCH, who of late years has carefully observed sections in East Surrey, tells me (1887) that "the section since made at Copthorne's Brickfield, Leatherhead, is much hidden, and the beds cannot be marked with accuracy; but, under a fairly thick capping of soil, there can be seen a good thickness of red mottled clay and greensand." The well here (see Well-sections) shows the approximate thickness of the beds, and is of interest as pointing to the occurrence of the estuarine shell-beds, which had not been noticed in the neighbourhood. I saw the junction with the Thanet Sand close by, in Mr. French's company (see p. 109).

At Ashstead mottled plastic clay occurs in a pond near the cross-roads, and the green clayey sand of the bottom-bed may be seen in an old pit in the Park, a little N.W. of the church.

From this part there are no sections nearer than Epsom.

At the kiln between the high road and the railway, a little N.E. of the London and Brighton Railway Station at that place, the order of the beds was as follows; though there was no complete section:—

Clayey soil and flints.

Reading Beds. { Red plastic clay with a little race.  
Bottom-bed. Greenish and grey clayey sand, 8 or 10 feet.  
Thanet Sand; about 15 feet shown.

Another and newer pit just east, and close to the railway, was in the following beds (1870):—

Loamy soil; 5 feet.

Reading Beds. { Grey and brown loam, 5 feet.  
Laminated grey clay, 4 feet shown.

From a local south-westerly dip the last bed soon rose up in the opposite direction.

In 1886 MR. H. H. FRENCH took the following note of the section here, of which he kindly gave me a copy. It differs from my earlier notes in showing a little drifted earth above and more divisions in the Reading Beds:—

		FEET.
Soil	- - - - -	1
[Drifted Earth.]	Weathered clay with flints, irregular	-
	Tough red clay with angular water-worn flints; the unaltered state of the above	4
	Dark grey band	½
	Drab sand, with a few small angular flints; very irregular	1
[Reading Beds.]	Mottled sandy clay, with pockets of sand; more clayey in the lower part; fills pockets in the bed below	2
	Deep green glauconitic very sandy loam	5
	Very pale greenish sandy loam, obscurely laminated, mottled; the lower part more clayey	3½
	Layer of pebbles.	-
	Pale greenish sandy loam, as above	to 1½

In the railway-cutting the bottom-bed may again be seen above the Thanet Sand. The section is now for the most part overgrown, but it has been thus described by PROF. PRESTWICH.\*

		FEET.
Reading Beds.	Brownish sand	3
	Green sand	2
	Coarse yellow and green sand, with flint-pebbles in its lower part	4
	Laminated grey clay	1½
Thanet Sand.	Fine white sand	12 to 15
	Grey sand	2
	Green sand and flints	½
Chalk.	- - - - -	-

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 98. (1854.)

At the Linton Lane brick-yard, on the other (northern) side of the high road, just opposite that above described, and over a quarter of a mile northward of the London and Brighton Station, the sections originally seen showed drifted clay, with flints here and there (sometimes a clayey gravel) overlying, at one place, plastic clay, and at another, white sand, about 2 feet thick, beneath which came the green clayey sand of the bottom-bed.

In 1886 however the section seems to have been clearer, judging by the following account, for which I have to thank MR. FRENCH :—

		FET.
Soil	- - - - -	1
Irregular flinty chalky gravel	- - - - -	5
Reading Beds.	Beautifully mottled clay, chiefly light-blue with red mottling	5
	Finely laminated reddish-blue clay, breaking up into fragments	4
	Tough reddish clay	3½
	Dark mottled blackish clay	1
	Clayey glauconitic sand, with large pockets of pinkish lavender-coloured sand in the upper part; seen to 8 inches.	

Eastward of this brickyard and two thirds of a mile N.E. of the London and South Western Station, is a newer one, opened since the six-inch Ordnance Map was made, for the account of which MR. FRENCH is again to be thanked :—

		FET.
Soil.	Black earth, with bits of chalk	½
Pleistocene (reconstructed Reading Beds).	Tough reddish-yellow clay, with pebbles; irregular pockets of sand at the base	3 to 3½
	Yellow red-mottled sandy clay, with pockets of sand	2
	Finely laminated reddish mottled clay, with carbonaceous markings	4
	Brown loamy clay, full of angular flints, and with some rounded	1 to 2
	Clayey glauconitic sand, with pockets of pinkish lavender-coloured sand (as in the last section); greener towards the base: the top is a water-worn surface with E. and W. hollows: - - - - - seen to	4

"The Pleistocene beds die out a few yards eastward, and are replaced by the mottled clays of the Reading Beds. The above note was taken in 1886; but in 1887, from the southerly working back of this face, less of the Pleistocene beds were shown, and red mottled clay was seen next beneath them."

Between Epsom and Ewell the bottom-bed takes up a large space at the surface. It was shown at the kiln, about half-way; where there was some eight feet of brownish-green sandy clay above the Thanet Sand; and the same may be seen in the road to the north. MR. FRENCH tells me that, in 1886, "the section at this old brickyard was overgrown, and hidden by talus; but the beds, from the base of the mottled clays, seem to follow the same succession as at Nonesuch Kiln. A section was cleared, with the spade, and sharks' teeth were found in the lowermost sand, overlying the dark basement-clay. The Thanet Sand seems to have been dug to the depth of 7 feet."

At Nonesuch Kiln at the time when I mapped the Tertiary beds of this neighbourhood (many years ago) there was in the larger pit a great thickness of valuable plastic clay of various colours; in the smaller pit, to the S.E., the bottom-bed, consisting of roughly laminated bluish-grey clay with green sand, many feet in thickness, was to be seen overlying the Thanet Sand. The structure of the bottom-bed here is somewhat like that which it has in the neighbourhood of Reading, on the other side of the London Tertiary District; but I did not find any traces of fossils in it.

At my second visit (in 1870) there was a clearer section of all but the lowermost beds, the succession being :—

Reading Beds.	{	Nearly black plastic clay, several feet.
		A little puce-mottled plastic clay.
		White sand and grey clay, from 0 to 6 inches.
		Red-mottled plastic clay, 7 to 10 feet.
		A little dark grey sand.

Clayey green sand.

Some 76 years ago a note of this Ewell section was published, and it is reproduced here because its author, MR. J. MIDDLETON, had, in those early geological days, a very fair notion of the order of these deposits. He says, "At Ewell . . . I found the fire-clay, in two or three layers of different qualities, rising from under the edge of the London clay. The uppermost of these beds is of a reddish or ruddy colour, with blue veins. The next is a bed of clay, about three feet thick, not much unlike fullers-earth, and this rests upon sand of a similar brown colour . . . beneath which may be seen the lower bed of white sand [Thanet Sand], and under that the chalk."\*

In 1886 MR. FRENCH noted the section, which must then have been in very good order, and he has kindly communicated the following measurements :—

		FEET. INCHES.	
Reading Beds about 30 feet.	Clayey soil, with flints	-	4
	Fine white loamy sand	-	5
	Red clay, with grey mottling, false-bedded, getting lighter in colour as it rises, top part more sandy	-	8
	Green red and purple clay, with pockets of red and white sand and a few pebbles; passing down into sand	-	5
	Inconstant layer of small pebbles; up to	-	2
	Coarse bright-green glauconitic sand, with more or less horizontal tubular borings, which are filled with very fine white sand, capped with red clay	-	6
	Coarse glauconitic ferruginous sand, with a tendency to false bedding	-	6
	Inconstant layer of red clay, up to	-	1
	Laminated clay, mottled greenish and reddish, with glauconitic sandy partings	-	9
	Highly ferruginous streaky sand	-	4
	Highly glauconitic sand, with partings of fine drab in the top 9 inches, and of red clay below	1	3
	Layer of black pebbles.		
	Greyish strongly glauconitic sand, with scattered flint pebbles (tending to run in layers) and pebbles of drab clay, some race; sharks' teeth at the base	1	7
	Finely laminated brownish loamy clay, with teeth of <i>Lamna</i>	2	-
	Bluish clay, tough and dicey, passing into the sand below	5	-
Thanet Sand	-	-	6

The bottom-bed may also be seen in the railway-cutting to the S.E., and in the road-cutting at Howell's Hill.

Mottled clay occurs by the turnpike-road near the lodge of Nonesuch Park, and also in the park just to the N.E., and there is probably a thick bed of it for some way eastward.

In a sand-pit on the east of Cheam Church a little of the bottom-bed was shown, and mottled clay has been found at Little Cheam and at Sutton.

\* *Monthly Mag.*, vol. xxxiv. p. 199. (1812.)

At Carshalton the boundary-line between this formation and the Thanet Sand is very doubtful, and between Carshalton and Croydon it is quite hidden by the gravel of the Wandle.

*Between the Wandle and the Ravensbourne.*

From Carshalton eastward to Croydon this formation is hidden under the gravel-flat of the Wandle Valley, beyond which it rises up to the light of day.

The outcrop is mostly very narrow, from the coming on of the Blackheath Beds, and from the way in which they cut into the Woolwich Beds, sometimes apparently even to the extent of reaching through to the Thanet Sand, and therefore wholly preventing an outcrop.

The following section was laid open at the Croydon Gasworks, Waddon, in making the second and larger gasholder in 1869. I did not see it, but had the account of the thickness of the beds from the foreman, and saw the various earths lying about.

	FEET.
Gravel	7 to 10
At one part silt and wood, with land and freshwater shells	$\frac{1}{2}$
Woolwich and Reading Beds. { Slate-coloured clay, $\frac{1}{2}$ sandy	2
{ Shell-bed, clay and rock, ( <i>Cyrena cuneiformis</i> and <i>C. cordata</i> )	about $\frac{1}{2}$
{ Mottled plastic clay, deeper in colour lower down: then brown and grey clay	- $\frac{1}{2}$ 9 $\frac{1}{2}$ to 12 $\frac{1}{2}$
{ Clayey green sand (bottom-bed), not sunk through	3
Total about	26

In making the neighbouring sewage-works (to the east) the Woolwich Beds were again found beneath the gravel. When I was there, in October 1859, no section was to be seen, but from the heaps of earth that had been dug out it was clear that the shell-beds were present, and I found the following fossils, often conglomerated together in masses:—*Calyptæa*, *Cerithium*, *Melania inquinata*, *Cyrena cuneiformis*, and *Ostrea*.

The cutting southward of East Croydon Station is in great part overgrown; but the Woolwich Beds may be seen here and there. The green sand with flint-pebbles, forming the bottom-bed, is the part that is most clearly shown. I also saw this bed just east of the railway in 1859; higher up the hill there is plastic clay.

PROF. PRESTWICH has given a general section of the beds at Park Hill\* from which I differ only as to the reference of the pebble-beds to the basement-bed of the London Clay: the latter consists in this neighbourhood of a clayey pebble-bed of no great thickness; whilst the greater part of these is sandy, I should therefore take them to belong to the Blackheath Beds, excepting perhaps the topmost foot or so; and the section would stand thus:—

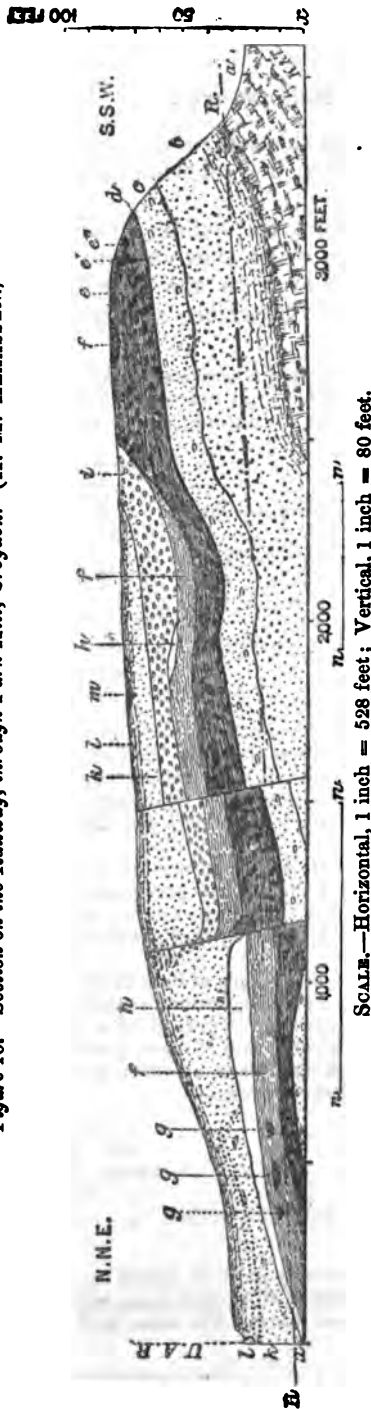
London Clay and its basement-bed.	FEET.
Blackheath Beds. Pebbles	say 9
Woolwich Beds. { Clay shell-bed	about 6
{ Mottled clay	25
{ Bottom-bed. Green sand with pebbles	5
Thanet Sand.	

In making the reservoir just east of the railway mottled plastic clay was found, and it may be seen on the footpath thence to Combe Lane, with the clayey pebbly greensand of the bottom-bed lower down. The same beds also occur just eastward of the Water Tower.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 99. (1854.)



Figure 10. Section on the Railway, through Park Hill, Croydon. (H. M. KLAASSEN.)



$n-n$  = Position of tunnels. These are now joined together as one tunnel.  
 $x$  = Datum-line of 200 feet above sea-level.  
 $R. R.$  = Level of the railway.

\* = Faults.  
 $m$  = Drift.  
 $a$  = Chalk.

1. Brown and grey laminated clayey sand, with ferruginous layers; water-bearing. Near the northern tunnel a dash of small flint pebbles at the base: up to 10 feet.
- k. Loose grey sand; with slight and discontinuous partings of impure pipe-clay, pellets of clay, and thin carbonaceous layers. About 5 feet from the base 4 brown clayey layers, up to 4 inches thick. Bedding irregular: up to 24 feet.
- i. Pebble-beds: up to 15 feet; divided as follows:—  
 Loose brown sandy pebble-bed; sometimes compact and with a sandy layer at top. Contains whole shells (as well as angular fragments, casts and impressions), carbonaceous fragments and pieces of calcareous sandstone. A sprinkling of very small pebbles at the top [? beneath the sandy layer]. On the western side of the southern cutting there is a mass differing from the above, and consisting of pebbles in loose brown sand, without fossils.
- Massive [Mostly small, but a few large, pebbles, in brown clayey sand, with casts and impressions of *Ostrea*. At base a band of *Ostrea* pebble-beds. &c. (marine). 2 feet 2 inches.
- Black pebbles [Small pebbles in grey calcareous sand, ferruginous at the base: with angular fragments, casts and impressions of shells: 1 foot.
- more or less [Small flint pebbles in brown clayey sand, with ferruginous layers and brown pudding-stones: fragments, casts and impressions of shells: 1 foot 2 inches.
- cemented [Black pebbles, angular pieces of shells, lignite and carbonaceous fragments, in blue calcareous clayey sand. Darker and more com-
- by calcareous cement. pact at the base, and with many casts and moulds of shells (marine and estuarine). Fossiliferous pudding-stone: up to 10 feet.

(Description of Fig. 10, continued.)

- h.* Hard white shell-bed (estuarine shells, mostly broken), with some carbonaceous fragments. Small flint-pebbles imbedded on the top surface, and a few 8 inches below. In the northern cutting, at the junction with the overlying bed, some tabular pieces of sandy limestone, up to 4 feet long by 6 inches thick, with shells. 2 feet thick on the north, increasing southward to 10 feet, and then soon thinning out: comes on again some way further south, for a little way, to the thickness of 2 feet.
- f.* Clay shell-beds, with pockets of lignite at *g*, in one of which *Coryphodon* was found. Details as below, total thickness 10 feet:—  
Brownish-grey clay. Oyster-bed. 3 feet 10 inches.  
*Cyrena*-bed. In central cutting, soft blue clay alternating with hard bands of pale blue calcareous clay (estuarine and marine shells): some specimens of *Cyrena* with the siphonal end upward, many with the valves united, some with the brown epidermis. In the northern cutting the shells are fewer, the hard bands are absent, some of the clay is dark and carbonaceous, lignite occurs, and remains of fish, turtles and gigantic birds are found, as well as fluviatile shells: the soft clay here contains plant-remains: up to 7 feet 3 inches.
- e.* Mottled clays: from 4 feet, on the north, up to 31; details as below, at the thickest part:—  
Brilliant ochreous, with traces of mauve; with calcareous matter: 7 feet 4 inches.  
Ochreous, with patches of greenish-blue and some mauve: 4 feet.  
Greenish-blue, with patches of mauve and some ochreous patches: jointed structure: 5 feet.  
Mauve, with greenish-blue and some ochreous patches: 4 feet 7 inches.  
Compressed lignitic matter: an inch.  
In the southern cutting, at *e'*, a lenticular bed of carbonaceous clay with many small crystals of selenite. At *e'* calcareous matter penetrates the whole of the mottled clay.
- d.* Black flint pebbles, up to 5 inches long, in lavender-coloured sand, with a thin hard brown ferruginous and carbonaceous layer at top. Some of the larger pebbles have the longer axis vertical. The colour (of the sand) faded after exposure to air: 1½ feet. [I should not class this with the bottom-bed, as Mr. KLAASSEN has done. See also pp. 188, 144, 154, for other occurrences of a like bed.]
- c.* Bottom-bed: about 13½ feet: details as below:—  
Green sand, with iron-stained veins and with some yellowish pebbles: 3 feet.  
Coarse greenish-brown sand, with veins of iron-staining and greenish-brown nodules (containing Crustacean remains): borings of Mollusca, up to 3 feet in depth: some greenish-grey flint pebbles: 6 feet 8 inches.  
Grey sand, with nodules cemented by calcareous matter: *Crustacea*: 3 feet.  
Brown clayey sand. *Ostrea bellouacina* (up to 9 inches by 7 in size), *Serpula*, teeth of *Lamna* and of *Oiodas* "not less than 700 . . . having been collected by one gentleman," a Crocodilian tooth, marine shells, including the new species *Perna croydonensis*: here and there some black flint pebbles: 3 feet.
- b.* Thanet Sand. Loose, pervious, with eroded surface. Towards the base of the cutting with iron-stained casts of irregular horizontal tubes, some filled with clay. Thickness, found by boring, 38 feet.

This Figure has been kindly given by the Council of the Geologists' Association.

When this neighbourhood was first mapped, in the absence of sections, I took the whole of the clay just south of the Addiscombe Road to be London Clay; but when resurveying here in 1870 (to divide the Blackheath from the Woolwich Beds) this was found to be a mistake, the outcrop of the last running in northward some way. I was then enabled to draw the boundary-lines with much greater accuracy, not only by reason of the sections, but also from having a much larger and more detailed map\* than the old and imperfect "one inch" Ordnance sheet.

One of the finest sections in the London district was laid open by the railway-cutting eastward of Park Hill Rise, and luckily for geologists Mr. H. M. KLAASSEN was living at Croydon whilst the line was being made; for he was a constant visitor and has carefully recorded all that was to be seen from time to time.† I had the advantage of seeing the cutting, with him, in October 1882; but the few notes I was able to take are far more than covered by his description, one of those monographs of sections that are by no means common, and from which the accompanying account is compiled (fig. 10).

Along the top of the southern part of the cutting, where the mottled clays are at the surface, they had weathered to a yellowish clay. The beds over the southern tunnel were partly seen in a pit, for ballast. Much water was thrown out along the top of the shelly clays, causing slips and slush.

There are some remarks on the plant-remains, by Mr. J. S. GARDNER, who says, of the mass of carbonaceous clay in the mottled clay, "though it abounds in vegetable matter, I am quite unable to detect any structure of value. There are undoubted traces of dicotyledonous leaves . . . but they are so decomposed and macerated . . . that they afford not the slightest clue as to the kind of plants to which they might have belonged. The fine parallel venation of Rush or other water-loving plants predominates." Of the specimens from the clay shell-beds, he says, "The plant-remains are mainly more or less fragmentary leaves of Dicotyledons . . . I have seen but two specimens of Ferns . . . I have also observed but a single Conifer, possibly a Cypress . . . Among Monocotyledons there is the usual profusion, in places, of rush-like fragments . . . The dicotyledonous leaves seem to be mainly evergreens . . . On the whole, the flora appears to be highly distinctive, and confirms what I had previously only suspected, that the Woolwich flora is essentially different from the Reading flora . . . The whole Woolwich and Reading Series represents the alternating estuarine and fluviatile conditions of a large river . . . I consider the 'blue clays' [shell-bed] to have been deposited in back-waters . . . The dark brown, or nearly black, lenticular patches of so-called lignite imbedded in them must have been deposited when the back-waters were isolated, and had become stagnant ponds, gorged with decayed vegetation, and too free from foreign sediment for the leaves to have been covered up until all structure had rotted away."

A pit in an abandoned brickyard near the top of the rising ground, south of the Addiscombe Road, about half a mile beyond the East Croydon Station (near the corner of the new Fairfield Road) gave the following section:—

Woolwich	{ Shell-beds, p 8 feet
and	{ Mottled clay, over 3 feet.
Reading Beds.	{ Light-coloured fine sand.

This must be close to the top of the formation, as just westward the Blackheath Beds seem to come on above.

Round here and to the east there are plenty of surface-signs of the clays, which must have a fair northerly dip, and the green bottom-bed may be seen at the edge of the little wood westward of Combe Farm.

Through Shirley Park the outcrop is rather doubtful, and then, as it turns southward and westward, is very narrow, the Blackheath Beds nearly sweeping over to the Thanet Sand; indeed at the western foot of the Addington Hills I was unable to map any Woolwich Beds, which there seemed to be quite overlapped by the pebble-beds of the overlying Series.

\* Mr. B. Latham's "Plan of the Parish of Croydon," 1868. On a scale of  $4\frac{1}{2}$  inches to the mile.

† *Proc. Geol. Assoc.*, vol. viii., no. 4, pp. 226-248. (1883.)

In mapping this last (in 1870) along the range of hills from here to Farnborough the sketch "6-inch" Ordnance Maps of the "Surrey and Kent Hills" were used, and from their superiority to the old small-scale map I was able to make many corrections.

East of Ballards there is again a very narrow outcrop of the formation now described, and mottled clay occurs in a pond on the westerly slope of the spur, but it seems to be again hidden by overlap within Addington Park. At the eastern part of the park however, signs of an outcrop are given by springs, &c., and the road down the hill north of the village shows the following section, though it is not very clear :—

Blackheath pebble-bed.

Woolwich and	{	Clay and shelly clay.
Reading Beds.		Mottled clay.
		Clayey greensand.

Thanet Sand.

About half a mile eastward the Blackheath Beds have been denuded off the ridge and an outcrop of the Woolwich Beds stretches northward, with a rather doubtful boundary, through the lower part of Park Wood, the clay shell-beds being plentifully shown in ditches and ponds, and eastward across the road from West Wickham to Wickham Court. In a well at the new house at Monk's Orchard, on the north-west, sand and gravel (Blackheath Beds) were passed through to a depth of 16½ feet, when an oyster bed three feet thick was found. I was told that this last occurred all about the neighbourhood of West Wickham.

Beyond the entrance to this bay-like outcrop we again find but a narrow one along the flank of the hill. At the corner of the wood westward of the Rectory the clay shell-bed and the green sand below are shown, and in the corner of the road by the Rectory there is clay just below the Blackheath pebble-bed. Beyond this the outcrop gets doubtful, and in less than half a mile the Woolwich Beds are hidden by the gravel of the Ravensbourne valley.

### *Between the Ravensbourne and the Cray.*

It is doubtful how far down the valley of the Ravensbourne this formation may next underlie the gravel, possibly all the way to the tract described as the Bromley inlier (p. 161), which in this case of course would not be an inlier; from the nearness of the London Clay outliers to the bottom of the valley however this is not likely, and it has been thought best to draw the outcrop-line across the valley between Hayes and Pickhurst Green.

By the former of these places the Woolwich Beds seem to rise up from beneath the eastern boundary of the Valley Gravel, there being springs thrown out from Blackheath pebble-beds, and clay occurring below the last.

From here the very narrow outcrop rises along the hill-flank south-eastward to Holwood Park, whence it again sinks, north-eastward, to the valley of the Cray.

On the road down Coney hill westward from Hayes Common, there is shown, below the light-coloured fine Oldhaven sand with pebbles, clay and shelly clay.

On the road down hill south-westward from the Fox Inn, at the southern end of Hayes Common, both shelly clay and mottled clay may be seen. PROF. PRESTWICH noticed here "two zones of the Woolwich shells with the mottled clays between them."\* Just beyond there seems to be a narrow inlet along the little hollow northward of Keston Heath, in parts of which there is clay.

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\* *Quart. Journ. Geol. Soc.*, vol. x. p. 99.

A little beyond the house in Holwood Park, and close to the hill-top, a small sand-pit marks the boundary-line, the section being:—

Bottom-bed of the Woolwich Series:—Brown and grey sand, with a few small flint pebbles at the bottom, 5 feet.

Nearly white fine sharp Thanet Sand.

Shelly clay (at one place with mottled clay) may be seen at various places, and about Cowlass Hill, westward of Farnborough, the fields are strewn with the pebbles of the bottom-bed.

MR. W. MORRIS, Engineer to the Kent Waterworks, writes to me that “in constructing the Reservoir at Cowlass, Farnborough, the section shown was very peculiar” and, from a rough sketch, it seems to have been in white Thanet Sand, 20 feet deep, at the highest part, for a length of about 40 feet, when this ends suddenly, by a fault bringing in the Woolwich Beds (and perhaps in part Blackheath Beds) along the lower part, for a length of about 150 feet, the depth at the end being 15 feet. Over the whole was a thin layer of “sand with pea-gravel.” The Woolwich Beds dipped slightly towards the fault, the section on the downthrow side of which was as follows:—

Clay and gravel.

Yellow clay and pebbles.

Blue clay, to the bottom at the fault.

Peat, rising up some way from the fault and occurring for 75 feet along the bottom until reaching a thickness of 5 feet at the further part.

MR. MORRIS adds that “the sharp division between the bright sand (P Thanet) and the other beds was very marked, and the occurrence of a thick bed of peat struck me as singular.” It is certainly an unexpected development of the lignite-bed of this series, no such thickness, I believe, having been recorded before.

At Farnborough kiln, at the western end of the village, I did not see any very clear section (1860, 61). The beds shown were:—

		FEET.
Woolwich and Reading Beds	Stiff bluish-brown and pale mottled clay	about 6
	Bottom-bed. Pale greenish-grey clayey sand, passing into the bed below	4
	Thanet Sand. Pale buff and white sand, to	12

The junction showed a northerly dip of 15°, which high angle must be very local.

### *Along the Valley of the Cray.*

From Farnborough this formation follows the Thanet Sand N.N.E. along the left side of the valley of the Cray, and the shelly clays and the green pebbly bottom-bed may often be seen.

From near St. Mary's Cray the narrow outcrop still gradually sinks to a lower level north-eastward, with the slope of the ground, towards Bexley.

Near Bexley the boundary-line is for the most part hidden by the gravel of the valley. From a slight uprise of the beds here there is an outcrop up the bottom of the small valleys westward of Lamorbey, north-westward to the end of the lake in Danson Park and northward towards Bexley New Town, the chief evidence of which is the occurrence of springs and the very damp nature of the lowest ground of these branching valleys.

From Bexley the beds rise slightly northward to the valley of the Thames.

The section down the hill south-west of Orpington is not so clear as when seen by PROF. PRESTWICH, so that I shall quote his description.

"The following section was shown in a road-cutting at Crofton Pound :—

	FEET.
Fine yellow sand. [This I believe belongs to the Oldhaven Beds.] -	6
Dark grey clay - - - - -	$\frac{1}{2}$
Mass of comminuted shells, chiefly <i>Cyrena cuneiformis</i> - - - - -	1
Yellow clay and concretionary slabs of earthy limestone full of <i>Ostrea bellouvacina</i> - - - - -	1
Light-brown clay - - - - -	$\frac{1}{2}$
Rough thin concretionary limestone full of <i>Ostrea</i> and <i>Cyrena</i> - - - - -	2
Woolwich and Reading Beds, 23½ feet. { Mixed brown and grey clay - - - - -	1½
{ Mass of broken shells ( <i>Cyrena</i> , <i>Melania</i> , <i>Cerithium</i> ) in yellow clay - - - - -	3½
{ Mottled bright red and light-greenish clay - - - - -	2½
{ Brown clay full of small flint-pebbles - - - - -	1
{ Bright yellow clay - - - - -	1½
{ Dark clayey green sand, passing down into very light-coloured loose green sand with a few thin layers of flint pebbles - - - - -	8

"Traces of the mottled clays are visible yet here."\*

The cutting on the South Eastern (Lewisham and Tunbridge) Railway at Orpington Station must have given a fine section when clear. When I saw it first the greater part was unfinished, and when again, in 1870, the sides were overgrown; however the following succession could be made out :—

Sand of the Oldhaven Beds, at the highest part.

Woolwich Beds	{ Clay.
	{ Shelly clay, with peaty earth at bottom.
	{ Clay.
	{ Pebbly green sand.

Thanet Sand, cut into from the end near the Station up to as far as the footpath across the line.

The lines of growth on the sides of the cutting show distinct and even bedding; dipping at a small angle along the line N.W.

MR. E. NASH has published the following details of the beds shown in part of this cutting† and he tells me that his notes were taken at about 300 or 400 feet from the Orpington end, that is to say, south-west of the highest part, and beyond the on-coming of the Oldhaven Beds.

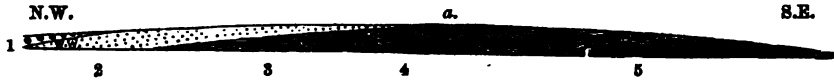
			FEET.
Woolwich Beds.	{	Vegetable clay earth	- - - - -
		Yellow clay	- - - - -
		Yellowish earth, with traces of broken shells	- - - - -
		Yellow earth, gradually getting blue and of a deeper colour downward; charged with fragments of shells, increasing in quantity with the depth	- - - - -
		Layers of perfect shells, compacted into a hard bed	- - - - -
		Very black soft earth, with some fragments of shells	- - - - -
		Dark pebbles and sand	- - - - -
		Hard green sand, with dark stripe at bottom	- - - - -
		Light-coloured clean [? Thanet] sand, not bottomed.	- - - - -
			[? about 11.]
			about 3
			[? about 4]
			2
			[? over 4]

The shallow north-western part was finished at the time of my first visit, and its section was as in Fig. 11.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 100.

† "A Lecture on Pre-Adamite London," pp. 30, 31, 8vo. London, 1879.

Figure 11. Cutting on the Lewisham and Tunbridge (South Eastern) Railway, Town Croft, S. of Chislehurst.



No scale. Exaggerated vertically.

- a. Wash of pebbles, in the hollows of the contortions of the shelly clay.
- |               |   |  |
|---------------|---|--|
| Oldhaven Beds | { | 1. Pebbles, a foot or two feet, at the northern end (Oldhaven Beds? or wash thereof).  |
|               |   | 2. Light-coloured sand, iron-stained at bottom.  |
|               |   | 3. Shelly clay, rising up at about 160 yards north of the bridge, and throwing out water. At and just beyond the bridge over the railway contorted. At bottom an oyster-bed, a foot or more thick, which is not affected by the contortions above, rising up about 60 yards north of the bridge. |
| Woolwich Beds | { | 4. Clay without shells.  |
|               |   | 5. Shelly clay, with the shells in the even planes of bedding.   |

In a pond (? an old pit) a little east of Crofton Court, the following beds were to be seen (1870) in descending order:—Shelly clay, black clay, and clay without shells. In the lane-cutting northward the green bottom-bed is shown, and in a sand-pit about a mile further (just west of the cottage named "Poverish" on the map) its junction with the Thanet Sand is laid open.

We now come to a set of cuttings on the London Chatham and Dover Railway, which gave one of the best sections of the Woolwich Beds, one of them indeed showing the greatest thickness of the shell-beds that I know of. Luckily I saw these cuttings when they were fresh and clear, but now the best of them are much overgrown and therefore their sections are hidden.

The sides of the cutting at St. Paul's Cray Common (Fig. 12) were slanting and wet, so that it was not easy to measure the beds. The shell-beds are 30 feet thick, and as usual the shells cause the beds to weather in planes parallel with the bedding. It will be seen from the figure that the dip follows the slope of the ground.

Just beyond there is a small shallow cutting (on one side of the line only) showing about three feet of clayey green sand (bottom bed).

In the next cutting (Fig. 13) which is also along the flank of a hill, so that the northern side is the largest, there is about a foot of black clay at top near the western end, most likely the same as the bed at the bottom of the eastern end of the first cutting. At the western end the "bottom-bed" is at the level of the rails, but the Thanet Sand at once rises eastward at about 2°: soon however the beds get flat, but as the level of the line falls eastward more of the sand is shown, the greatest thickness seen being about seven feet. The junction of the two formations is even.

The next two cuttings are small, and in Thanet Sand with drifted loam, &c.; but at St. Mary's Cray Station there is a deep cutting showing:—

A thin wash of flint-pebbles.

Bottom-bed. Green sand with layers of pebbles, about 8 feet.

Thanet Sand, about 30 feet.

From the two cuttings shown in Figs. 12, 13 the general section Fig. 14 is made up. It will readily be seen how much of it is from each cutting, to both of which it serves for a detailed description of the beds. The same references are used in the three figures.

Along the road north-west of St. Mary's Cray Station the bottom-bed is shown, overlying the Thanet Sand, and higher up are shelly clays; further north these last are often to be seen, in ponds (as at Scadbury and Frogna) or turned up by the plough, and sometimes the first also.

Figure 12. Cutting on the London Chatham and Dover Railway at St. Paul's Cray Common.

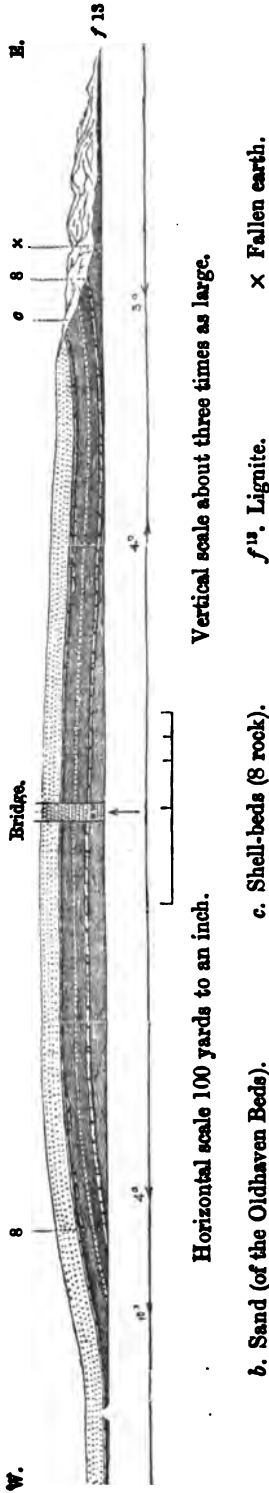


Figure 13. Cutting of the London Chatham and Dover Railway W. of St. Mary's Cray Station.

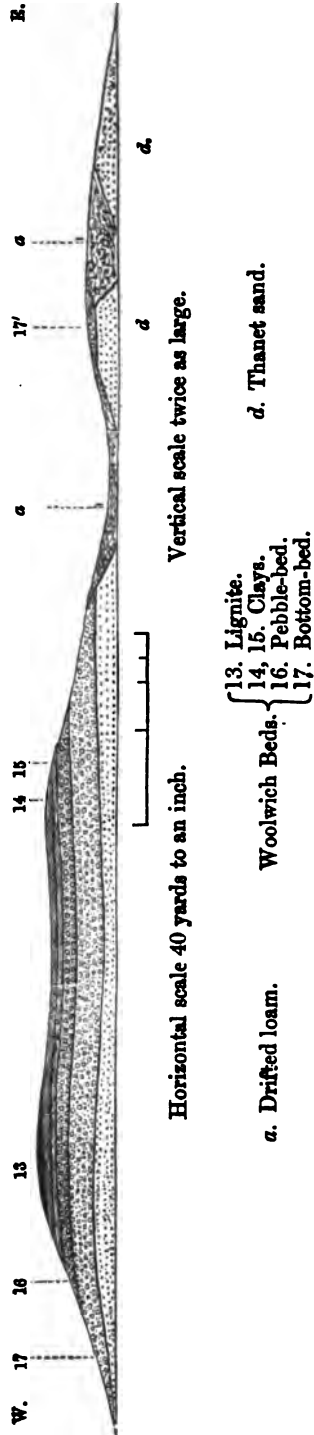




Figure 14. Detailed Section of the Woolwich Beds W. of St. Mary Cray.

(Scale 8 feet to an inch.)

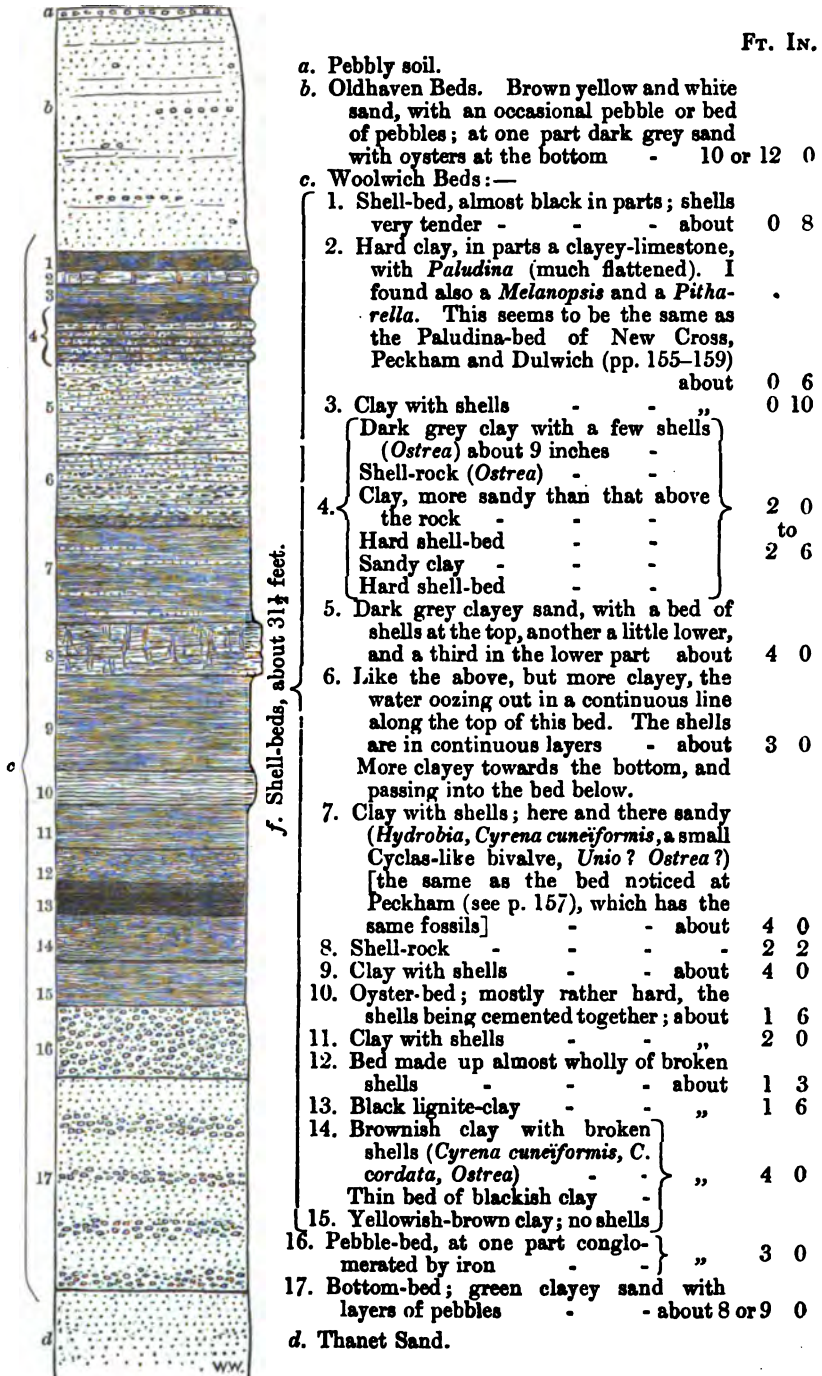


Figure 15. Eastern Part of the Cutting on the Lewisham and Dartford (South Eastern) Railway through Bushey Leas Wood, W.S.W. of Bealey.  
(Northern side.)



1. Wash from the higher beds, filling a hollow.

London Clay ... { 2. Clay; the bottom part bedded, sandy and brown or marly and greenish, one bed of the latter kind being somewhat hardened and containing *Panopæa* and another bivalve shell; at most about 10 feet; hardly any on the southern side of the cutting  
3. Basement-bed. Black pebbles in brown clay with fragmentary fossils at a few places, 12 to 15 inches; scoops slightly into the bed below (see also p. 228).

Oldhaven Beds { 4. Light-coloured loose sand, here and there with masses of pebbles and shells; at most 10 feet.  
5. Loose light-coloured shell-bed, almost wholly made up of fragments of shells; sandy in parts; with pebbles (often a good many), and traces of current-bedding; sometimes hardened into a sandy shelly conglomerate; from 2 to 5 feet.

Woolwich and Reading Beds. { 6. Shell-beds; the very bottom part rather sandy, the rest dark bluish-grey finely bedded clay, with the shells in the planes of bedding; 8 feet or more.  
7. Sand, the top part clayey and somewhat ironshot, the rest pale-grey and sharp; nearly 5 feet.  
8. Pale-grey clay, mottled with yellow or purple and red (the representative of the mottled clay of the Eltham cutting, p. 166, or of the "bottom-bed," or of both); about 5 feet.

9. Light-coloured Thanet (?) Sand, the upper part darker and more clayey, the rest sharper; about 3 feet shown.

Near Bexley a good section was made by the railway-cutting (Fig. 15) which I saw when it was fresh and comparatively clear. From the loose nature of the beds, however, the section was of course much hidden. Moreover some of the beds seem to change their character, thereby adding to the difficulty of clearly distinguishing them. On account of the slope of the sides one could not measure the thicknesses accurately.

The cutting reaches a long way westward, but that part was not clear at the time of my visit, when ground was opened for about 550 yards, the cutting then being shallow. Just beyond the bridge the upper division (sand) of the Oldhaven Beds showed a little gentle current-bedding. At 100 yards from the bridge the basement-bed of the London Clay thickened to three feet or more, and it seemed to occur for another 100 yards, but it was hard to say where it ended off, as the pebbles wash over some way. The shelly clays of the Woolwich Beds seem to sink before getting 300 yards further, but before they are lost to sight they are capped by a clayey pebble-bed about six feet thick.

The green bottom-bed was noticed a little west of the road from Bexley to Bexley New Town (or Bexley Heath), about half way between those places, and at the edge of the wood close to and on the southern side of the high road at the eastern end of the latter place the following beds were to be seen :—

Brown sand.

Grey and brown clay, with shells at one part, 2 feet.

Brown sand full of shells (*Cerithium*, *Cyrena*, *Ostrea*) from 8 inches to 2 feet.

Brown sandy clay.

The edge of the wood is not as marked on the old one-inch Ordnance Map but further down the hill.

## CHAPTER 10. LOWER LONDON TERTIARIES (WOOLWICH AND READING BEDS).

### SOUTHERN OUTCROP—(continued).

*Up the Southern Side of the Valley of the Thames from the Cray to the Ravensbourne.*

At Crayford the Valley of the Cray opens out into that of the Thames, and the outcrop of the Woolwich Beds winds northwards to Erith.

From Erith the Woolwich Beds run westward, along the flank of the hills bordering the Thames, to Greenwich, and in this course their outcrop is often reduced to nothing more than that of the pebbly greensand at the bottom (which however is rather thick here), because the Blackheath Beds irregularly overlap and cut off the shelly clays, &c. The outcrop is at first very narrow, little more than a broad line on the map, but it is distinctly traceable and of a winding nature, being cut back deeply along the side-valleys of East Wickham and of Blackheath.

Northward of Bexley there is plenty of evidence of the shelly clays in the fields and ditches, and the green bottom-bed is shown in the lane about half a mile S.E. from Northumberland Heath; but there is no good section of this formation for nearly three miles.

A sand with concretionary stone and a clay with broken shells, that were shown in the highest part of the section of the pit for the Erith brickyard, have been referred by mistake to the Woolwich Beds;\* they really belong to the Brickearth series, though the shells in the clay are broken up Woolwich shells. There are however some singular masses of the Woolwich Beds here, as noticed by MR. A. TYLOR† together with some of the overlying Blackheath Beds and also a little London Clay. These masses, of which figures are given further on, seem to be the remains of an old landslip, for they are well below the boundary-line of the Woolwich Beds, and moreover are underlain by the Brickearth. The nearest patch of London Clay being about three quarters of a mile off, and that too small to be mapped (see p. 231), and the nearest mappable mass being about two miles off, this "fossil landslip," as one may call it, is of all the more interest.

The great sand-pit at Erith Station is now (1887) cut from the Blackheath Beds, or perhaps even from the London Clay down to the Chalk, the section being as in Fig. 16 (overleaf), which however was drawn many years ago, when the pit had not been carried so far back, and the Blackheath Beds were not touched by it; but were added from the evidence of a small pit close by on the west (? since absorbed).

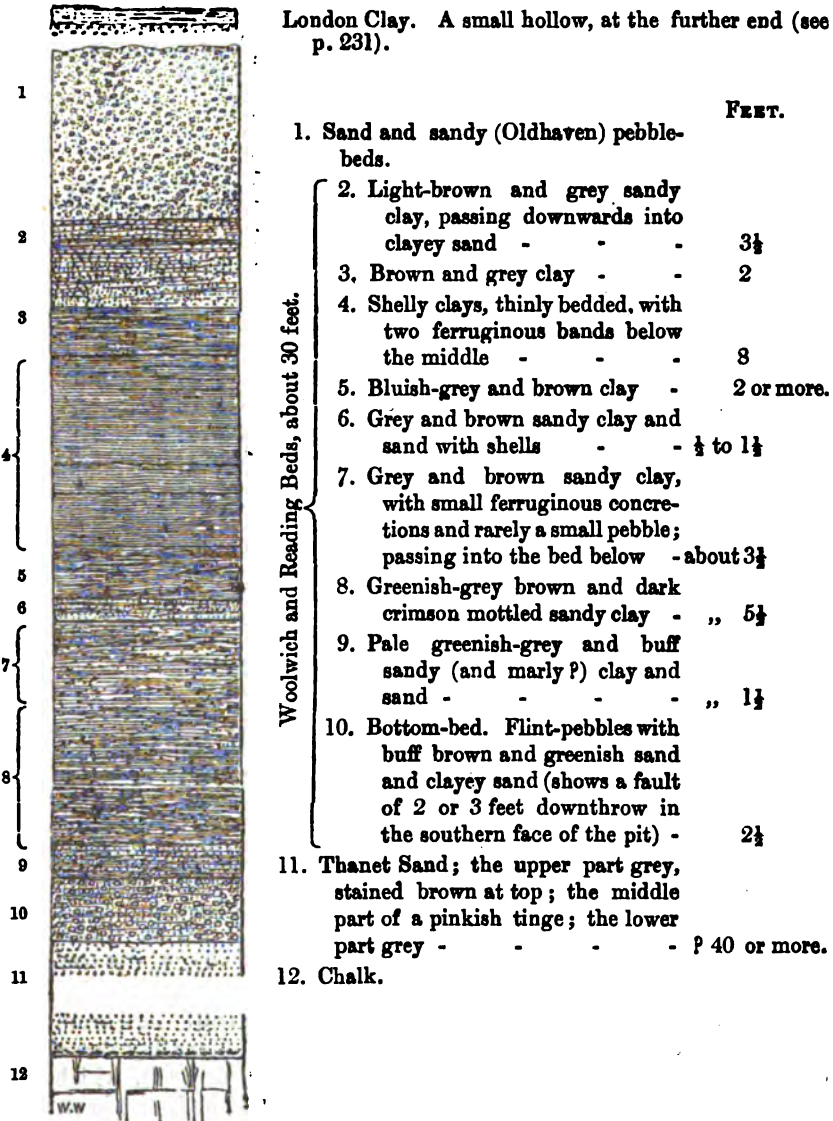
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\* *Quart. Journ. Geol. Soc.*, vol. xxiii. p. 97. This paper was published before, and Mr. Tylor's paper after, I had examined the section.

† *Quart. Journ. Geol. Soc.*, vol. xxv. p. 88. The London Clay escaped Mr. Tylor's notice.

Figure 16. General Section at Erith Sand-pit.\* (1867.)

(Scale 8 feet to an inch.)



\* This section must be much better now than when PROF. PRESTWICH dismissed it with the remark that "the line of demarcation between them (the Thanet Sand and the Woolwich Beds) can hardly be traced: the two sands are almost exactly alike, and the pebble seams are wanting. But the organic remains here assist us, as a band, marked by the occurrence of the *Ostrea Bellovacina*, defines the line of separation of the two groups."—(*Quart. Journ. Geol. Soc.*, vol. x. p. 102.) This latter statement is in addition to the description now given, for the bottom-bed was not to be easily got at when I saw the section.

It should be understood that the whole of the Woolwich Series is only to be seen at the southern side, at the highest part, about the middle (where the measurements were made). The Blackheath pebble-beds (not there present) rest erosively on the Woolwich Beds, and where the pit cuts through the little wood the former rest on shell-less clay (? 7).

West of Erith the Woolwich Beds crop out along the bottom of the little valley to Bedenwell, as is shown by the springy nature of the ground.

In Belvidere Park some small road-cuttings, just below and east of the Tower (marked "Summer House" on the old Ordnance Map), show the pebbly greensand (bottom-bed) dipping southward and with clay above. At the top of the hill the Blackheath pebble-bed comes on.

Close to the back of the houses on the southern side of the lane about a third of a mile south-west of the Belvidere Station some small pits showed a good thickness of the bottom-bed, with a slight northerly dip. The section, made up from three pits, which were at slightly different levels, and from a fourth just above them (southward) was as follows:—

Blackheath pebble-bed (in the highest pit only).

Bottom-bed of the Woolwich Series.	{	<p>Brownish and greenish clayey sand, with flint pebbles at top and bottom, and with small scattered pebbles, lumps of soft "race," and streaks of white calcareous earth throughout. A layer of oyster-shells about the middle, and traces of another just below. 7 feet or more.</p> <p>Grey and brown sand, clayey in parts, and with thin layers of clay, dark grains, here and there a pebble, and at bottom a scattering of pebbles. 7 feet or more.</p>
---	---	--

Light-buff Thanet Sand (in the lowest pit only), the top part with a few irregular winding hollows filled in with the greener and coarser sand (and here and there with a pebble) from above.

The cutting on the road down the hill southward to Abbey Wood Station gave the following section:—

Blackheath pebble-bed (at the higher part) not very markedly divided from the underlying bed.

Bottom-bed (Woolwich Series). Up to about 12 feet of light-grey and greenish clayey sand, partly with clayey layers, with a few pebbles scattered throughout, and in four beds (one of them at the bottom).

Thanet Sand, the top 8 or 10 inches stained brown and yellow.

PROF. PRESTWICH noticed "traces of laminated clays" at one part between the Blackheath pebble-bed and the pebbly green sand.\*

The cutting on the high road down Bostall Hill again shows a great thickness of the bottom-bed. Just above the lane to Bostall Farm there is light-greenish-grey clayey sand, about four feet thick, with pebbles at the bottom; a little lower down between three and four feet of this pebble-bed; and below the lane, where the cutting is deep, some 12 feet of greenish sand, with layers of pebbles throughout, but less towards the base, which is brownish. Above the bottom-bed, which can hardly be less than 16 feet thick, there are signs of clay, and the Thanet Sand is cut into below, the junction being irregular, as was also the case in a former pit near by, of which PROF. PRESTWICH says that the "pebbly bed has been as it were splashed into the soft and yielding surface of the underlying Thanet Sands."†

The same author observes that the clay with shells crops out by East Wickham Church.‡

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 107.

† *Ibid.*, p. 101.

‡ *Ibid.*, p. 106.

At Wickham Lane Brick Works, less than half a mile N.W of the church, the higher, or south-western side of the pit, showed the following succession in 1887 :—

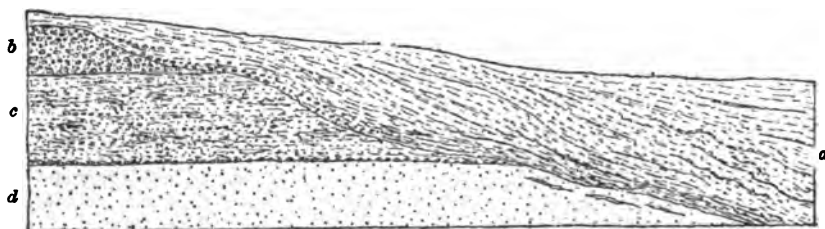
	FEET.
Brickearth, gravelly, the lower part bedded, and looking like the bedded loam and sand (forming the top part of the Woolwich Beds) disturbed and decomposed -	7 or 8
Nearly white sand -	about 5
Flint pebbles in whitish sand, compact Sand. At top, for nearly 2 feet, green, passing down into less green, then green-grey, and then grey (stained brown), with pebbles here and there -	5
Flint pebbles, splashed into the underlying sand -	over 15
Thanet Sand.	about 1

On the shorter north-western face, adjoining the above, the Brickearth cuts off the Woolwich Beds, going down sharply towards the Valley, as in fig. 17, from a sketch which MR. GOODCHILD was good enough to make for this Memoir, and it is peculiar how the dragging-down action of the Brickearth has pulled along a layer of green sand, from the top of the mass of sand. The Eocene green sands seem to be tenacious, and so lengthen out under dragging-force to a remarkable extent, instead of giving way altogether. Other examples of this miniature "shearing," if one may apply that term to so small a thing, have been described in other Memoirs.\*

Figure 17. Section at Wickham Lane Brickworks. 1888.

S.W.

N.E.



- a. Brickearth (River Drift), with pebbles dragged down from *b*, and with strips of green sand dragged down from *c*.  
 Woolwich Beds. { *b*. Pebbles in whitish sand.  
                   *c*. Greenish and grey sand, with pebbles here and there.  
 d. Thanet Sand.

At the adjoining brickyard, just westward, a like section, of brickearth cutting northward across the greenish-grey sand of the Woolwich Beds and the underlying Thanet Sand, was seen (1887); whilst a small pit just to the south, on higher ground, showed laminated loam and sand, above the Woolwich shell-beds (which were seen at the entrance). These loamy beds my colleague MR. GOODCHILD, to whom I am indebted for seeing these new sections, was disposed to class with the Brickearth; but they seemed to me rather to represent the beds, of like character, which form the top part of the Woolwich Series at Charlton and Lewisham (see *post*): besides the lithological likeness the evenness and flatness of these beds seemed to me hardly to consort with the oblique sweep of the Brickearth close by, and probably they will be found to underlie the Blackheath pebble-beds, which come on close by.

\* The Geology of the Neighbourhood of Stowmarket, p. 10 (1881). The Geology of the Country around Ipswich, &c., p. 132. (1885.)

Another brickyard, barely separated from the last and reaching up to the Cemetery, gave a good section of the Woolwich Beds at the southern and eastern part: a section of the more interest from proving the absence there of the pebble-bed, 5 feet thick, seen at the Wickham Lane Brick Works, only an eighth of a mile east, and the presence of the shelly clays, which have been wholly swept off by the Blackheath pebble-beds, about the same distance to the north, at the corner of Plumstead Common, in a pit soon to be described. Here, as in the other two brickyards, just north, the Brickearth comes on sharply, cutting off the higher beds. The succession seen was as below:—

	FEET.
Top part tumbled and slipped. Brown clay (? decalcified shell-beds) - - - - -	76
Brown clay; with a layer of <i>Ostrea</i> and <i>Cyrena</i> ; then 2 layers of <i>Ostrea</i> - - - - -	1
Light-brown sandy shell-bed, with broken <i>Cyrena</i> and some <i>Ostrea</i> ; resting irregularly on the bed below about	2
Very pale grey sand: the top 6 inches or more mostly stained brownish (from above); 5 or 6 feet down thin layers of clay set in: about 3 feet deeper interrupted layers of pebbles set in: then the sand gets darker (greenish-grey): pebbles at the base, in greenish sand, splashed into the sand beneath - - - - -	over 20

#### Light-coloured Thanet Sand.

At the Woolwich Cemetery, west of the Wickham Lane brickyard, the bottom-bed is touched in graves less than 100 yards south of the lower chapel, whilst further southward the shell-beds are found, and at the highest parts some four or five feet of the Blackheath pebble-beds over sand. The extreme south-western corner is most likely on London Clay.

A sand-pit marked on the old Ordnance Map, at the south-eastern corner of Plumstead Common, behind Hope Cottage, and just north-east of the cemetery, gives a good section from the Blackheath Beds to the Thanet Sand, the Woolwich Beds being represented by the bottom-bed only, as at Abbey Wood, the beds above having been cut off. For the note of the junction of the Chalk with the Thanet Beds I have to thank Mr. J. G. GOODCHILD:—

Blackheath pebble-beds, with a little laminated clay at the base in parts, about 12 feet.

Woolwich Beds. Light greenish-grey sand, the top 12 or 14 inches with seams of clay, the lowest 2 feet or so with a few scattered pebbles, and a bed of them at the bottom, ? 10 feet.

Fine almost white Thanet Sand, the lower part more clayey, with green-coated flints at the base; about 56 feet.

Chalk.

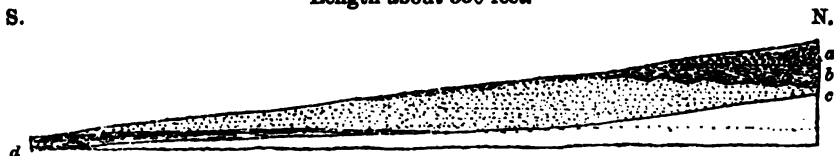
In a cutting in the highest part of the grounds of the Woolwich Union (Plumstead) a good junction of the bottom-bed with the Thanet Sand was laid open in 1870.

Just west of the Workhouse, the cutting down a new road leading to Cage Lane, gave, in 1887, the section shown in fig. 18. This was seen with Mr. GOODCHILD, who was good enough afterwards to make the drawing for the figure:—

The sandy shell-bed was again seen, beneath the Blackheath Beds (see p. 231) near by.



Figure 18. Section down the Road west of the Workhouse, Plumstead, 1888.  
Length about 350 feet.



a. Blackheath Beds. Pebbles and sand.

Woolwich  
Beds.

Clay, thin: P decalcified shell-bed, not shown in figure.

b. Fine light-brown sometimes loamy sand, with broken shells (*Cyrena*) in places (P elsewhere decalcified). This, the sandy shell-bed of neighbouring sections, rests in a series of alight scoops on the bed below: not over 3 feet.

c. Grey sand, with clayey layers, and here and there a pebble; a good thickness.

d. Black flint pebbles, below which must come the Thanet Sand.

At Plumstead Station the cutting is in the bottom-bed over Thanet Sand. The southern side has been cut back, just west from the station, showing a better section of the former than originally, there being about 15 feet of pale green-grey sand, underlain by a pebble-bed, up to 2 feet thick (1887). This capping of the Woolwich Beds seems to extend westward nearly to St. Ann's Street, on the southern side, the pebbles having been seen by Robert Street; but further westward there is none of the Woolwich Beds for some way (as far as can be seen now that so much of the cutting is overgrown) and the Thanet Sand is covered by a wash of loam and pebbles. Where Maxey Road crosses the line however there seems to be a little of the bottom-bed, but whether in a detached hollow, or joining on to the mass just south, cannot be seen. The pebbles here are not confined to the base of the sand.

At the brickyard north of Bramblebury House (south of the railway) I could see no good section, but the shell-beds and sand were shown, and at top a washy clayey pebble-gravel. At another brickyard, north-west of the same place, there was at the eastern part a little of the first over yellow sand, and at the southern edge the same bed of yellow sand over grey and greenish-grey sand with a few seams of clay, more than 8 feet dug into, the lower part more clayey and the bottom part a regular green sand.

In a large old pit between the railway and Crescent Road the shell-beds and the greenish sand were again shown (though the section was for the most part overgrown and hidden) and also the Thanet Sand.

A pit on the eastern side of the road (Brook Hill Lane) in the little valley about half a mile southward of Woolwich Arsenal Station gave the section below (1863):—

		FEET.
Oldhaven and Blackheath Beds.	A little sand lying somewhat irregularly on the next bed.	
	False-bedded pebble-bed, a mass of which wedges into the sand below	8 or 10
	Light-coloured sand, with a few clay-partings	12 or 15
	Clayey shell-bed	1½
	Shell-beds. { Laminated dark bluish-grey clay, in which I saw no shells	1½
Woolwich Beds.	Loamy shell-bed, bottom not seen	3½
	Bottom-bed. Light green-grey sand (shown a little lower down). A small cut on the same side of the road just above the section (south) showed 2 or 3 feet of this, with a few pebbles, and underlain by a brown pebble-bed about a foot thick, below which are a few inches of the light-coloured Thanet Sand.	

In the brickyard about a quarter of a mile N.N.E. of the Royal Military Academy a pit on the flank of the small valley passed through :—

Blackheath pebble-bed, full of oyster-shells.

Roughly laminated light-grey loam (3 of the Loam Pit Hill Section, p. 154).

At another pit, higher up, there is London Clay, and at a third there is beneath the clay a little light-coloured loam, like the basement-bed at the kiln on Plumstead Common (see p. 244).

On the northern side of the Royal Marine Hospital the flank of the hill facing the railway was laid bare and the following beds exposed in 1861 :—

Pebbles, resting irregularly on the bed below.

Woolwich Beds.	{	Light-coloured sand, 12 or 15 feet.
		Shell-beds, about 8 feet; the upper part clayey, the lower sandy; an oyster-bed near the top.
		Light-coloured sand, partly white, 15 feet (or more?) shown: lower part grey and greenish (bottom-bed).

One of the best known sections of the Woolwich Beds is that of the large and oft described ballast-pit at Charlton, touching the railway south of Woolwich Dockyard, which lays open the series of beds shown in Fig. 19, reaching from the Blackheath Beds right down to the Chalk.

The great Chalk-pit at Charlton has been cut back so as to touch what was once a separate pit, at a higher level, between it and the church, and to give a continuous section from the top part of the Woolwich Beds, through the Thanet Sand to the Chalk. In 1878 the high (western) part showed a very even junction of the Woolwich Beds and the Thanet Sand, for over 100 yards.

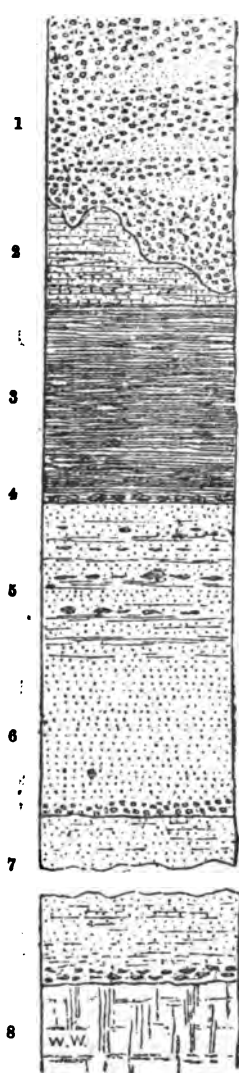
The bedding, as shown by the junctions, and by the flint-layer in the Chalk, is almost flat, but slightly inclined southward.

The succession was as follows, the numbers of the beds being the same as in Fig. 19.

		FEET.
Woolwich Beds.	2. Alternations of sand and clay - - -	3 or 4
	3. Shell-beds. { Clay with shells - - -	2 or more.
	{ Oyster-bed - - -	1½ "
	{ Clay shell-bed, resting somewhat unevenly on the bed below -	1 to 1½
	4. Stone; in parts ironstone; a few fossils -	1½ or more.
	{ Brown and grey sand; hardened (especially at top, where it is marly); clay-partings in the lower part; a few ironstone-concretions -	3
	5. Sands { Brown sand with ironstone-concretions -	1
	{ Sand with clay-partings: upper part yellowish (through the iron from above) but the rest almost white; false-bedded in parts, about	7
	6. Bottom-bed. { Light-grey somewhat greenish clayey sand - - -	2 to 2½
	{ Do. Do. with flint-pebbles -	1½ or more.
	{ Sand with green grains (at S. end only) -	1½
	7. Thanet Sand, the bottom part of a light-greenish colour, and with the usual green-coated flints at the base. The junction with the Chalk even.	
	8. Chalk with flints, a well-marked layer of flints 10 or 12 feet down: about 25 feet.	

Figure 19. General Section at Charlton.

(Scale 8 feet to an inch.)



1. Blackheath Beds. Sandy pebble-bed, false-bedded; the lower part very fine in places, and with many fossils (see pp. 236, 237); in part with a little sand; resting irregularly on, and sometimes cutting through the bed below: many feet.
2. Alternations of sand and clay, a few feet to nothing. This is clearly the same as the "leaf-bed" of Lewis-ham (3 and 3' of fig. 21, p. 154). I am at a loss therefore to understand how it could be said, in 1876 (this cut having been published in 1872) that "the presence of this bed at Woolwich was never before known," (*Proc. Geol. Assoc.*, vol. iv. no. 9, p. 536). The extent of the bed is indeed shown over a rather wider range, under the name "striped sand and loam," in Mr. DE LA CONDAMINE's map of 1850. (*Quart. Journ. Geol. Soc.*, vol. vi., p. 441.)
3. Dark grey clay, with shells in close and even layers, marking the bedding (see pp. 212, 213), with an oyster-bed less than a foot from the bottom. 6 to 8 feet.
4. Thin hard concretionary calcareous layer in parts.
5. Brown yellow and grey sand and loam, with layers of concretionary ironstone and of clay, some of the former containing shells (*Cyrena*, &c.)? from 4 to 7 feet, passing down into the next.
6. Buff and greenish sand, with pebbles in the bottom part, resting evenly on the bed below. ? 7 feet.
7. Thanet Sand. The nearly white part used in pottery-work, the lower and more clayey part (here known as "black-foot") for moulding in iron-foundries (as also is the lower sand of the Woolwich Beds). Green-coated flints at the bottom. A cast of *Cyprina* and of a fish-vertebra, and casts of *Pholadomya* have been found in this sand at Charlton.\*
8. Chalk with flints.

\* H. J. JOHNSTON-LAVIS, *Proc. Geol. Assoc.*, vol. iv. no. 9, p. 532. (1876.)

Just north of Charlton church the road-cutting (on the eastern side only) showed sand with partings of clay and with a scattered layer of pebbles at one part; and in another large old pit, on the west of the road, the shell-bed occurs at a slightly lower level, the section being, as far as could be seen (for it was much hidden):—

Clay shell-bed; about 4 feet seen.

Light-grey clayey sand with lumps of ironstone, and at the bottom a layer of them; about 4 feet.

Brown ferruginous sand.

Here too the lower part of the pit is in Thanet Sand.

The section given by PROF. PRESTWICH,\* “from two or three small pits,” was, perhaps, from this pit, and it is repeated here, as it is in part an upward continuation of the foregoing:—

		FEET.
Woolwich Beds.	e. Light-yellow sand striped with clay -	12
	d. Light-yellow sand with thin seams of iron-sandstone -	5
	c. Dark grey clay with shells -	6
	b. Hard concretionary limestone -	2
	a. Pebbly green sand -	10
Thanet Sand.		

PROF. PRESTWICH noticed “the occurrence on the upper surface of a thin seam of iron-sandstone in the upper part of bed *d* of well-marked *ripple-marks*.”

At the northern mouth of the Blackheath railway-tunnel the bottom-bed may be seen at the top of the eastern side, and again in the road just west (Combe Farm Lane), the cutting up which also shows brown clay with shells: higher up light-coloured sand with pebbles in places; and at the top of the hill pebble-beds, the last two belonging to the Oldhaven Series. The junction with the Thanet Sand is also cut into in a small pit just west, where there is a little greensand at top.

Since this neighbourhood was mapped, Westcombe Park has been laid out for building, and many sections have been opened, from the year 1879 onward. Some of these I saw with my former colleague MR. T. V. HOLMES, who constantly visited the Park and who has described the sections, the following account of which is taken from his paper,† with a slight change, from further observations, which he has kindly communicated, namely the inclusion of the whitish sand with the Blackheath Beds, instead of with the Woolwich Beds (as in the paper), a course to which I was inclined when seeing the sections. This sand MR. HOLMES says, “has been much worked since 1883, and the beds above show many changes in detail, and more connexion with the whitish sand than they seemed to have at first.”

In Beaconsfield Road, about halfway between the junctions with Hardy Road and with Humber Road the following was the succession seen in the cutting:—

Blackheath Beds.	Pebble-bed (which thickens up the hill southward).
	Orange-brown sand; 2 feet 2 inches.
	Laminated clay and sand; 1 foot 2 inches.
	Pebble-bed, with many large pebbles; from 4 inches to over a foot; resting unevenly on the bed below.
	Whitish sand, with thin partings of clay; 13 feet seen, and not then bottomed, but only a gap of 2 or 3 feet left (to the Woolwich shell-bed). [I noted over 15 feet of this sand, but did not see the junction with the pebbles above.]

That the clay shell-beds occur just below is shown by the wetness of the ground and by the presence of fragments of shells.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 103.

† *Proc. Geol. Assoc.*, vol. viii., no. 1, pp. 60–64. (1883.)

The next section, on the bank dividing Coleraine Road from Humber Road was as below :—

Blackheath Beds.	Pebble-bed (capping the hill).
	Brown sand, with clayey partings towards the base; 2 to 2½ feet.
	Pebbly-bed; up to 3 feet; resting irregularly on the next. Light-coloured sand; 7 to 9 feet seen, not bottomed.

The clay shell-beds crop out just below, on the southern side of Humber Road, and going westward along this side of the road signs of the same occurred here and there.

A few yards east of where Foyle Road joins Humber Road the following section was noted :—

Blackheath pebble-beds; 16 feet.	
Woolwich Beds.	Shell-beds; about 5½ feet (clay 4 feet, a trace of the oyster-bed, and clay 1½ feet).
	Clayey bed, with soft calcareous matter and concretionary nodules of clay and ironstone; 3 feet.
	Brownish sand.

In 1879, in company with Mr. HOLMES, I noted the following section, on Humber Road, in a cutting then being made, through the ridge near the northern side of the park, the beds being measured on the higher, or southern side :—

		FEET.
Blackheath Beds.	Pebble-bed, partly coarse, resting irregularly on and dovetailing into the next	over 16
	Fine buff sand, 4 or 5 feet, but almost absent on the other (northern) side	
Woolwich Beds.	Clay shell-beds	4 to 6
	Greenish sandy clay, with large nodules of stone at top (partly ferruginous) and with calcareous matter throughout. In parts only, and passing down into the next	about 5½
	Clayey pale green sand	
	Pale sharp sand	2 to 3
	Clayey greensand (up to 4 feet shown at the western end of the northern side)	2

This section must lie between the last two given by Mr. Holmes, and the whole set show that, as he has remarked, the Blackheath Beds rest on an eroded surface of the Woolwich Beds. Mr. Holmes has compared the section of the shell-beds here with those at Charlton and Lewisham, noticing that the oyster-bed has here dwindled away almost to nothing, whilst the shelly clay above is twice as thick as at those places, that below being about the same in all.

At my visit a little mottled clay was seen on the western side of Mycenæ Road, opposite the road to the east.

The large old pit on the flank of the hill a little south-west of the Greenwich Union is overgrown, but the Blackheath (?) pebble-bed and the shell-bed are to be seen, as well as the Thanet Sand, and in the hollow at the lowest part Chalk, the small outcrop of which mapped here (so small that it has sometimes escaped the colourist of the map), would perhaps not have been shown but for the artificial exposure.

At Greenwich the bottom-bed was seen at the re-entering angle of the boundary-line west of the Park, at the western side of the Park, below the Observatory, by the avenue on the north-east (where, close to the foot of the hill, there is a thickness of some feet of pale green clayey sand, more clayey towards the top, whilst higher up there are the Blackheath pebbles), and again at Croom' Hill on the western edge of the park.

In a small pit, in private grounds, on the hill-flank between Hyde Vale and Point Hill there was, in 1870, the following section :—

Woolwich { Mottled loam, and traces of shelly clay.  
Beds. { Pebbly greensand, over 10 feet.  
Thanet Sand.

Between Blackheath Hill and Morden Hill is a very large and deep old pit, now much overgrown, and in private grounds, but which must once have given a fine section. It is in great part inaccessible, but I was enabled to make out the following succession (1870) :—

Blackheath pebble-bed.  
Pebbly green sand of the bottom-bed.  
Thanet Sand.  
Chalk.

In a small pit about half way between this and Lewisham Hill the bottom-bed was to be seen resting on the Thanet Sand.

On the hill-flank just east of Lewisham Station (looking south), and close to the railway, the Thanet Sand is capped by the bottom-bed, consisting of green clayey sand with some small flint-pebbles, and on the northern side of the road a little further eastward the Blackheath pebble-beds cap the latter.

The sides of the railway-cutting at the southern mouth of the Blackheath tunnel are now overgrown, but the section has been recorded by PROF. PRESTWICH, as follows :—\*

	FEET.
Blackheath pebble-bed	10 to 12
[Woolwich { Brownish sand	2
Beds.] { Broken-up shells in light-coloured clay with pebbles	4
{ Broken-up shells in greenish-grey clay	2
{ Light-green sandy clays, mottled red and grey	7
{ Light-greenish sands with a few pebbles [bottom-bed]	6
Thanet Sand.	

The bottom-bed may be seen at many places along the cutting westward, and at some parts the fine light-coloured Thanet Sand also, the junction of the two seeming to be slightly waved.

In the digging for the foundation of the School and lecture-room on the southern side of the railway at the Blackheath Station, green plastic clay (mottled with red), brown clay with shells, and light-green clayey sand (bottom-bed) were found.

In a brickyard about half a mile W.S.W. of Blackheath Station the laminated clayey sand was also shown, with a little pebble-gravel at top in parts; and in digging for the foundations of houses along a road just to the south-east the succession of beds was :—

Clay and gravel (Woolwich Beds ?) about 11 feet.  
Bottom-bed, about 2 feet of green sand.  
Light-buff Thanet Sand.

At the brickyard by Manor Lodge, Lee, the same bed, of sand with layers of clay, is worked, and has a slight southerly dip. Lower down, towards the brook, there is pebble-gravel (Valley Drift), with broken-up shells from the Woolwich Beds, more than seven feet thick in a small pit.

At another brickyard, now long given up, on the eastern side of the high road about half a mile southward of Lewisham Junction Station, the following beds were found :—

A little pebble-gravel.

Woolwich Beds { Laminated clayey sand and sandy clay, bottom not shown.  
Said to be 12 feet thick, and to be underlain by:  
Shell-bed (*Cyrena*), at the lower part an oyster-bed. Sunk through in a well, in which this bed was succeeded by:  
Clay 4 or 5 feet, and then  
Sand.

The railway-cutting through the low hill east of Lewisham Church gave a very good section of the bottom part of the London Clay, separated by a mere layer of the pebbly Blackheath Beds from the "striped sands." Figure 20 is

\* Quart. Journ. Geol. Soc., vol. x. p. 104.

Figure 20. Cutting on the South Eastern (Lewisham and Tunbridge) Railway, E. of Lewisham Church.



By some mischance I have forgotten to note the scale of this drawing. It is exaggerated vertically.

a. Thin irregular capping of pebble-gravel, in great part false-bedded, more clayey at the east.

London Clay { b. Grey clay, in parts apparently reconstructed.

{ c. Flint-pebbles in clay (basement-bed), six inches to a foot.

d. Blackheath Beds. Small black flint-pebbles in sand, a few inches to a foot.

Woolwich Beds { e. Finely and evenly bedded alternations of sand and clay, the upper part more sandy and the lower part more clayey; 20 feet.  
 { f. Dark bluish-grey clay with shells (*Cyrena*). By the western bridge I saw a large flat block of shell-rock containing  
*Cerithium*, *Melania iniquinata*, *Cyrena cuneiformis* (very perfect specimens), *C. dalwickensis*? (without the colour-stripes),  
 and *Ostrea*.

from a drawing of the southern side of this cutting, made in 1864, since which time the sides have been turfed and the section hidden.

The contrast between the irregular way in which the gravel rested on the beds below, and the even and conformable junction of the London Clay with the Lower London Tertiaries was striking, and also the sinking of the latter eastward, with the slope of the ground, at an angle of from  $3^{\circ}$  to  $5^{\circ}$  beyond the further bridge.

*Up the Southern Side of the Valley of the Thames above the Ravensbourne.*

On the western side of the Ravensbourne the Woolwich Beds crop up opposite Lewisham, and thence run northward to Deptford, whence the outcrop turns westward to Peckham and then south-westward up the little valley to Dulwich.

The junction with the underlying Thanet Sand is seen only near the Ravensbourne, being thence hidden under the gravel and brickearth at and west of Deptford.

Northward of Peckham, the Woolwich Beds are wholly hidden by the Brickearth and Gravel and then by the Alluvium, but their position may be fairly traced from the many wells and borings sunk through them (see Well-sections and Borings *post.*) These sections show that the junction with the Thanet Sand turns round until, south of Bermondsey, it runs eastward, reaching the Thames somewhere between Rotherhithe and Deptford, the junction with the London Clay following a like course, and reaching the Thames at Bermondsey. The flat tract of Deptford, Rotherhithe and Bermondsey is therefore geologically a planed down part of a dome.

One of the best exposures of the Tertiary formations near London is at Loam Pit Hill, between New Cross and Lewisham, where the beds from the London Clay to the Chalk are laid open, the complete section being as in Fig. 21.

The account here given, which differs but little from that published by DR. BUCKLAND in 1817, is made up from three large pits, all close together. In the most northerly alone (Mr. Lee's) is the Chalk touched, and here the middle and lower parts of the Woolwich Beds are mostly hidden by a thick deposit of brown pebbly brickearth and gravel, which rests irregularly on various beds.

The London Clay and the underlying sands were shown at the higher part of this pit, and also in the most southerly one (Mr. Sparks'), whilst the shell-beds, pebble-bed, and bottom-bed of the Woolwich Series were clear only in the more central pit (Mr. Sparks').

At the eastern end of the Lewisham Cemetery, south-west of Loam Pit Hill, the pebbly basement-bed of the London Clay occurs three feet or more down, with sand below. Lower down an oyster-bed has been found in places, and below it a nine-inch bed of clayey limestone, with a few pieces of shells, and here and there a number of small univalves (*Hydrobia?*).

At the brickyard about a mile eastward of Nunhead Cemetery, the pit, on the eastern side of the lane, shows:—

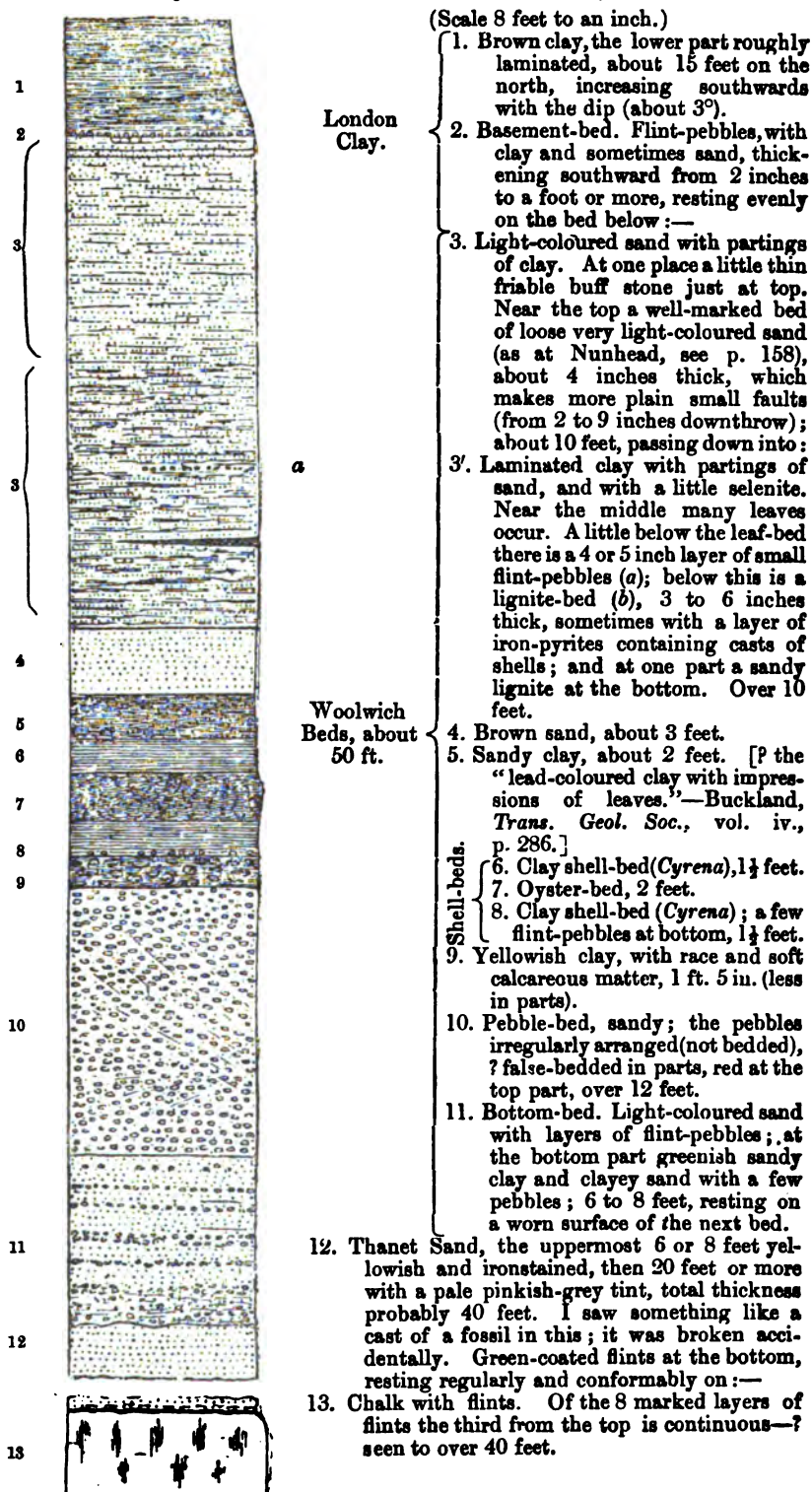
A little brown clayey sand (and wash).

Shelly clay, about a foot, and clay with "race" (almost septaria), of irregular thickness.

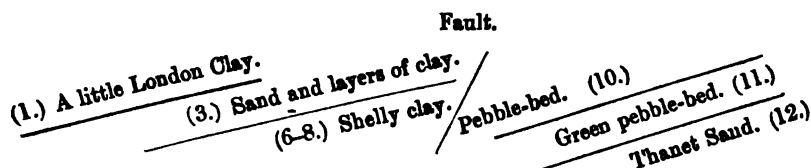
Light-coloured sand, about 7 feet shown.



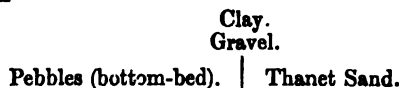
Figure 21. General Section at Loam Pit Hill, Lewisham.



On the South London Railway, just northward of Loam Pit Hill, a long cutting reaches from a little west of the North Kent line to a little east of that of the London Brighton and South Coast. At the western end there is a little London Clay over fine light-brown sand, the junction however being better seen in pits on either side of the line; there are no pebbles at the bottom of the clay. Rather more than 100 yards from the end a fault (the continuation of that on the North Kent Railway near by) with a westerly downthrow, [? 10 or 15 feet] crosses the cutting, the northern side of which was the clearer at the time of my visit (1870), and gave the section roughly shown below, the figures being the same as those of the corresponding beds in Fig. 21.



The green pebbly "bottom-bed" comes up about 20 yards eastward of the fault, and the Thanet Sand at 30 yards. At first sight the thick sandy pebble-bed at the top, on the upcast side, would be taken to belong to the Blackheath Beds, which it is much like; but it must be the same as that near the bottom of the Woolwich Beds at Loam Pit Hill (Fig. 21, p. 154). Further eastward there is a capping of Drift (consisting of clay underlain by gravel, chiefly of pebbles, but partly of subangular flints) which cuts off the pebble-bed in great part, and about 120 yards beyond the bridge (itself about 220 yards from the end of the cutting) the gravel is underlain by Thanet Sand, which is brought against the bottom-bed by a small fault with westerly downthrow, the section being—



The section continues, with Thanet Sand under gravel, to the other side of the next bridge (100 yards), beyond which the Drift seems to sweep down to the bottom of the cutting; then the Thanet Sand again rises, and between this and the next bridge a boss of chalk also. The eastern end is in chalk-with-flints, in great part much broken up, and with the flint-layers shattered and irregular: westward of the Lewisham High Road a thick mass of the gravel, with loam and sand, sweeps down into the Chalk, and is false-bedded in both directions along the line; whilst eastward of the road there is only a small irregular capping of loam and gravel.

The large brickyard at Counter Hill, about a quarter of a mile south of the New Cross Station (North Kent Line), was at the junction of the London Clay and the Woolwich Beds. The pits were not deep, and the best section that I have seen, at about the middle of the yard, was as follows:—

London Clay.	{	Brown and bluish-grey clay, in part roughly laminated, with a little selenite, 8 or 10 feet.
		Basement-bed. A clayey pebble-bed, generally from 8 to 12 inches, but 18 inches occasionally, resting on a slightly worn surface of the underlying bed.
		Very light-coloured sand, with a few broken layers of very small flint-pebbles, 2½ to 2¾ feet.
		Brown clay and sand, 5 to 9 inches. The representative of the thick "striped sands" of Lewisham (? thicker in other parts of this yard, and sometimes with lignite at bottom).
Woolwich Beds.	{	Blackish sandy clay with fossils ( <i>Unio</i> ), 1½ feet.
		Clayey septarian limestone (the "Paludina-bed" of Peckham, &c., here almost without <i>Paludina</i> ), <i>Unio</i> , <i>Cyrena</i> ; 6 inches.
		Dark grey clayey sand, with shells near the top. Much like the bed above the stone, but more sandy and less black. 2¾ feet shown (to water).

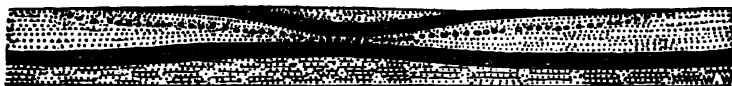
There were lying about some pieces of bedded sandstone, somewhat like the Dulwich rock, with *Paludina*, *Hydrobia*?, and *Melanopsis*. The list of fossils found in this yard is given at pp. 212, 213.

The cutting on the North Kent Railway southward from the New Cross Station was reopened for the purpose of widening the line, and I was thus enabled (in 1863) to see a great part of it. Just south of the station the section was :—

Valley Drift. { Resorted clay and loam, with flints.  
Gravel, mostly pebbles.  
Woolwich Beds. Sand with layers of clay.

Further south there was less of the loam and gravel, but the top of the slope not having been recut the highest parts were not shown. The Woolwich sands were false-bedded; with some layers of flint-pebbles; the bedding regular, and a good deal of clay in some beds. The section, Fig. 22, was taken on the eastern side, halfway between the station and the first bridge.

Figure 22. Part of the Cutting on the North Kent Railway, just S. of the New Cross Station.



Dots, sand. Lines, clay. Round marks, pebble-bed, 6 or 8 inches thick.

On the other side, and nearer to the station, there is a sandy shell-bed (*Cyrena*) at the bottom, and, judging by the water, clay must occur close below.

Still further south the pebble-bed shown in the above figure is two feet thick in parts, but irregular and somewhat clayey.

Just beyond the bridge a mass of mixed-up brick-earth, sand and gravel hides the beds below; but beyond the little hollow that runs across the line the sand with layers of clay is again touched and there are two small faults in it.

Thence past the second bridge and the short tunnel, the cutting was not re-opened at the time of my visit: at the southern end of the tunnel however I saw many feet of the sand with layers of clay, capped by made ground, and from thence to the next bridge the widening was finished and the sides bricked-up. Beyond this the cutting gets shallow and then shows only brick-earth and resorted gravel, whilst a little further there is a little light-coloured sharp sand above the loam, and a little light-brown sand below, but without gravel. Still further south the cutting is through higher ground and in lower beds (see p. 114).

The cutting on the London and Brighton Railway S. of the New Cross Station is not clear now, but accounts of it have been published by SIR C. H. GREGORY,\* and by MR. H. WARBURTON,† from which the following section is taken, with further remarks of my own, in square brackets :—

		Ft.	In.
London Clay.	Yellow clay.		
	Blue clay [with many and large pieces of selenite. The lower part laminated]	10 to 15	0
	Flint-pebbles; [basement-bed] -	1	10

\* *Proc. Inst. Civ. Eng.*, vol. iii. p. 138. (1844.)

† *Quart. Journ. Geol. Soc.*, vol. i. p. 172. (1845.)

		Fr.	In.
Woolwich Beds.	Fine fawn-coloured sand	0	3
	Lignite	0	$\frac{1}{2}$
	Fine fawn-coloured sand	2	0
	Ferruginous sand with fossils ( <i>Ostrea</i> , <i>Cerithium</i> )	0	4
	Loose grey sand with fossils ( <i>Cerithium</i> )	0	8
	Strong blue or black clay	0	10
	Black clay and sand with fossils ( <i>Ostrea</i> , <i>Cerithium</i> )	0	9
	Black dirty sand	0	4
	Dark sand with fossils (oyster-shells, &c.)	0	6
	[Clayey] calcareous stone with fossils [ <i>Paludina</i> -bed]	0	6
	Decomposed stone and sand with oyster- shells	0	3
	Plastic clay.		

PROF. PRESTWICH'S account differs from the above, and is therefore added.\* The difference is, perhaps, owing to the observers having measured the section at different spots:—

		FEET.
London Clay.	Clay	40
	Basement-bed; flint-pebbles in ochreous sand	1 to 2
Woolwich Beds.	Yellow sand	$2\frac{1}{2}$
	Clay and sand, with shells occasionally	3
	<i>Paludina</i> -limestone, with teeth, bones and scales of fishes, <i>Hydrobia Parkinsoni</i> , <i>Melanopsis buccinoides</i> , <i>Paludina lenta</i> , <i>Unio</i> <i>Deshayesi</i> , and traces of vegetable im- pressions	$\frac{1}{2}$ to 1
	Sand and shells	6
	Clayey sand and shells	5

A little north of the second bridge (from the station) the basement-bed is at the same level as the hard *Paludina*-bed a few feet to the south, whilst a little further south it is again found at the same level, as if there were two small faults.

The cutting of the Effra Branch Sewer along the lane going north-east from Nunhead Green was wholly in the Woolwich Series, and to a great extent in the shell-beds. In Lausanne Road, New Peckham, east of St. Mary Magdalen church, I saw lying about many fossils, clearly from various beds: there were a few pieces of hard coarse sandstone, like that of Dulwich (see p. 159), pieces of oyster-rock, of sandy shell-beds and of clayey shell-beds, some of the last with very perfect fossils. I found in a stiff laminated clay *Hydrobia*, *Melania inquinata*, *Cyrena cuneiformis*, *O. cordata* (large and plentiful), *Corbula*, some very small bivalves, and impressions of leaves. The most noteworthy occurrence perhaps was that of the *Paludina*-bed, a pale grey clayey limestone, mostly crowded with the shells of *Paludina lenta*, here generally massed in the centre of the bed, causing it to split along the plane of the fossils. In this the new genus *Pitharella* was found.

The cutting for the same sewer through Nunhead Green gave the following section (1860):—

London Clay { Clay, about 8 feet.  
Basement-bed, pebbles, 12 or 18 inches.  
Sand of the Woolwich Beds.

The brickyard at the northern point of the Green, was in the latter formation, and in 1863 I saw in it the section shown by Fig. 23. Another pit showed sand over clay.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 104. (1854.)

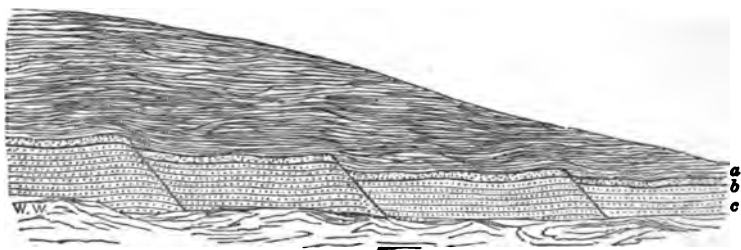




Great numbers of fine fossils were got here during the progress of the works (1860), and there is a good collection of them in the Geological Museum, Jermyn Street. A list is given on pp. 211-213.

At the brickyard about a quarter of a mile S.E. of Brockwell Hall there was a long section, in great part hidden by fallen masses of London Clay, the following beds however being shown towards the middle, the clearest part of which is shown in Fig. 24.

Figure 24. Section at Brockwell Hall Brickyard, near Dulwich (1863.)



- (a.) London Clay. Stiff, brown, roughly laminated and jointed (so as to break up into cuboidal pieces), rather sandy towards the base, where there are a few flint-pebbles and some green grains.
- (b.) Oldhaven Beds? Buff sand, with shells, 6 to 9 inches.
- (c.) Woolwich Beds. Light-coloured sand, with many thin layers of clay, evenly bedded, 6 feet shown.

At the more westerly part of the section the upper sand, which there seems to be rather thicker, is in many places hardened into a crumbling stone, full of fossils, a list of which is given at p. 236. The lower sand is the same bed as that which at Loam Pit Hill, Lewisham (see p. 154) underlies the London Clay, and contains leaves. There are three notable things in this section:— 1. That there is no distinct and separate “basement-bed” to the London Clay, that bed being represented merely by the scattered pebbles and green grains in the bottom part of the clay. 2. The upper sand may perhaps represent the Oldhaven Beds, being rather like bed c of the Upnor section, near Chatham.\* 3. I saw seven small faults with a downthrow of from half a foot to a foot, not simply slips in the Woolwich Beds, but affecting the junction with the London Clay, three of which are shown in the figure.

Along the lane about a quarter of a mile N.E. of the brickyard an oyster-bed (of the Woolwich Series) is shown; and in the sides of the brook alongside of that lane further southward, sand, clay, and a shell-bed of the same formation may be seen for some distance. About a quarter of a mile N.N.W. of Dulwich College a shell-bed is again at the surface, and there is some of the regular mottled plastic clay in the brook-channel about where it is now crossed by the railway, southward of Half Moon Lane. In some holes dug for the foundations of a bridge under the Peckham and Sutton (L. B. and S. C.) Railway a little eastward I saw 3 or 4 feet of shelly clay, underlain by pale grey and yellow mottled clay, the top part of which was sandy.

The above described outcrop of this formation west of Dulwich is very nearly an “inlier,” being almost surrounded by the overlying London Clay. Indeed it is possible that it may be quite surrounded, and that the London Clay of Herne Hill and Dulwich Hill may join in the valley between, in which case only the most eastern part of this area would join on to the main mass of the outcrop.

The only section in the Woolwich Beds that I have seen in the flat northward of Peckham was laid open at Rotherhithe in making the East London Railway, from the southern mouth of the Thames Tunnel, a detailed drawing of which was made and a tracing therefrom kindly given to the Geological Survey by MR. B. BURLEIGH.

\* Memoirs of the Geological Survey, vol. iv. p. 144. (1872.)

## CHAPTER 11. LOWER LONDON TERTIARIES. (WOOLWICH AND READING BEDS.)

### SOUTHERN OUTCROP (*continued*).

#### *Inliers, South of the Thames.*

##### *Bromley.*

At this town there seems to be an inlying exposure, although it is much hidden.

The well at the waterworks in the bottom of the valley of the Ravensbourne, near Shortlands Railway Station, touches the Chalk at a depth of not more than 70 feet (see *Well-sections, post*), and this depth seems to be wholly through Thanet Sand, capped by the gravel of the valley-flat. Unless the Blackheath Beds sweep down on to the Thanet Sand here, there must of course be a narrow outcrop of the Woolwich Beds between them, but possibly quite hidden by the gravel.

On the Bromley side of the valley the height of the ground alone is enough to suggest an outcrop of the Woolwich Beds along the base of the hill, the upper part of which is formed of the thick deposit of pebbles of the overlying Series; and further sign of the same is given by the marked change of slope down the flank of the hill, the sharp angle of the scarped pebble-beds ending somewhat suddenly and being replaced by a much gentler one, as may be well seen in walking from Shortlands Station to Bromley, by the field-path. This change of slope however may be owing to a mass of sand underlying the pebble-beds (as at Bromley Station) and belonging also to the Blackheath Series; but signs of a less pervious bed are given by the line of ponds along the flank of the hill south-eastward, just where the change of slope takes place, and also by the springs both here and northward.

In a field at the edge of Bromley Hill Wood, and nearly half a mile northward of Shortlands Railway Station I saw (in 1871) a little of the clayey green sand of the bottom-bed turned up by the plough, and from this one would infer that the outcrop extends beyond Bromley Hill House on this side of the stream.

Beyond Bromley Station however we find clearer signs, and there at least may be quite certain of the existence of an inlier.

The cutting just east of the station is overgrown, except at the western end, where it has been cut back on the southern side, for a coal-store, the following beds being shown:—

Sand (Oldhaven Beds) mostly light-coloured, but brown and ferruginous in the lower part. Most likely the sand below the pebble-bed; about 10 feet.

Shell-bed. In most parts a friable stone almost wholly made up of shells (*Cyrena*, amongst others a cast of *C. dulwichiensis*, *Ostrea*, *Melania*) with a few scattered flint-pebbles. About 4 feet shown.

A clay shell-bed has been found below I was told.

The upper beds continue along the cutting eastward, and at the highest part there are pebbles at the top.



The second bed may belong to the Oldhaven Series, but the shelly clay found below it must belong to the Woolwich Beds.

A good section of a thick mass of the shelly clays was made by Mr. COLLES CHILD in 1870 in the Palace Grounds, on the slope close to the old bath-house just south-eastward of the Palace, the order being as follows. The analysis given further on is of a specimen from the lowest shell-bed here.

Shell-beds	{	Bedded clay with <i>Cyrena</i> , the upper part much weathered ; about 6 feet.
		Oyster-bed ; about 2 feet.
		Dark clay with <i>Cyrena</i> , finely bedded ; over 2 feet.

Grey clay, rather sandy.

How far eastward up the little hollow the Woolwich Beds may crop out is very uncertain : indeed the beds that occur in that direction are rather perplexing (see p. 223) ; but as in the well at the Gasworks the Chalk was not found until a depth of 150 feet had been gone through, it is reasonable to infer that this Series has dipped underground there, and the sections at the two neighbouring kilns seem to favour that view, as far as one can tell at present.

#### *Sundridge, Camden, and Bickley Parks.*

A larger and more marked inlier, with many good sections, reaches through these three parks, along the valley between Bromley and Chiselhurst, for a distance of about  $3\frac{1}{4}$  miles.

At its eastern end this inlier has been artificially connected with the main outcrop on the east by the railway-cutting south of St. Paul's Cray Common (Fig. 12, p. 137).

The small cutting on the London Chatham and Dover Railway through the northern edge of Hawker Wood (or Great Thrift, as it is called on the Six-inch Ordnance Map) gave the following section at its western end :—

Grey London Clay, at one part a few pebbles at the base, and a little sand below. The cutting for the cart-road just south of the line showed a clayey pebble-bed at the base.  
Oldhaven Sand.

Eastward the shelly clay of the Woolwich Beds rises up from beneath the last, and is in its turn underlain by sand, laid open to a depth of three or four feet only, the lower part with layers of clay. Still further the beds again sink and the shell-bed alone was to be seen, but only to a thickness of about three feet, and composed as below :—

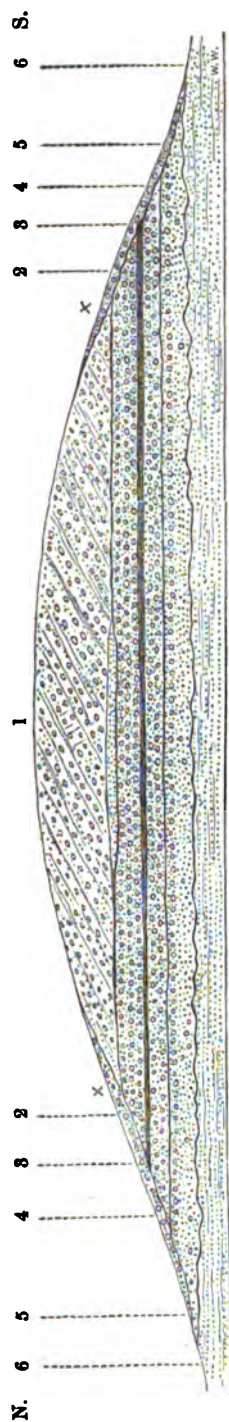
Grey clay with shells.  
Clayey sand with casts of shells.  
Shell-rock with *Ostrea* and *Cyrena cuneiformis* ; in parts a coarse sandstone like that found at Dulwich (see p. 159), about 6 inches.  
Clayey sand with broken shells.

The next cutting, about a third of a mile westward, is through about six feet of brown Oldhaven Sand overlying about three feet of bluish-grey clay with broken *Ostrea* and *Cyrena* ; and the pits in the brickyard just north showed clays without shells, in parts a mottled plastic clay.

From this part north-westward for some way the mapping of the narrow outcrop is somewhat doubtful, from the absence of sections, and from the presence of houses and enclosed grounds and woods ; but the green bottom-bed may be seen at a small pond in Bickley Park. In the ditch at the southern edge of Sundridge Park, where the footpath crosses, the shelly clay crops out ; there are other signs of clay on the west, and the shelly clays again appear by the ponds at Park Wood.

In the pond at the south-western corner of the garden on the northern side of Sundridge Park there is a little mottled clay, and just above there has been a brickyard, probably in a like bed, as I was told that the clay was mostly red, and somewhat soapy to the touch.

Figure 25. Cutting on the South Eastern (Lewisham and Tunbridge) Railway at the North-western Corner of Camden Park, Chislehurst.



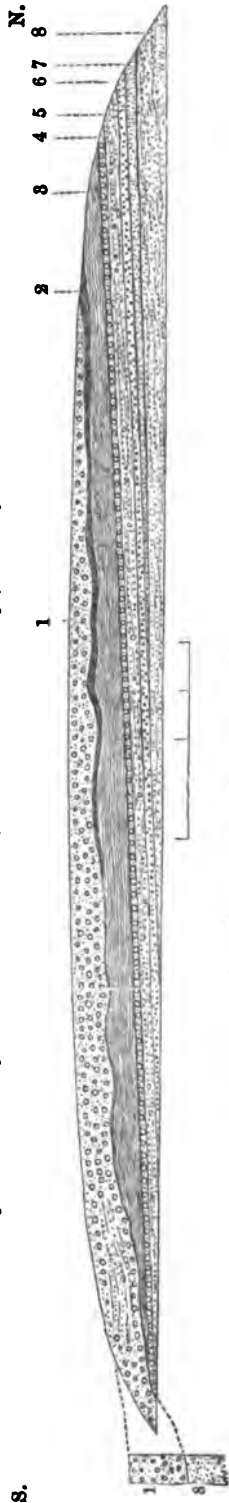
Scale, vertical and horizontal, 60 feet to an inch.

x. Wash of pebbles, &c. on the slopes.

1. Pebble-bed, fossiliferous, false-bedded, and in parts hardened into a conglomerate along the planes of false-bedding (the rock-bed of the pit near by, see p. 227) ; sometimes with a little greenish or light-coloured sand at the bottom ; about 25 feet.
2. Pebble-bed, much like the above, but more evenly bedded and not false-bedded ; fossiliferous, except in the lower part, the shells mostly perished ; hard blocks in parts, and at the middle a marked black pebble-bed, partly hardened ; about 8 feet (? less on the north, more on the south).
3. Green and red mottled plastic clay, mostly about a foot, with a layer of white earth at top and bottom, the upper of which may be owing to the decomposition of the shells in the pebble-beds above, by the infiltration of water and the deposition of their carbonate of lime from the water when it reached a less permeable bed, as suggested to me by PROF. MORRIS.
4. Irregular pebble-bed, the upper part whitish and irregularly bounded beneath by a brownish layer (bleaching by infiltration, and by deposition of the dissolved colouring-matter at a lower level) with mostly a little white earth below ; greenish at bottom, and with white earth ; about 5 feet.
5. Bottom-bed. Rather pale green sand ; with a bed of pebbles, a foot or more thick, some two feet down, and scattered pebbles below. At one part a layer of white earth above and some patches of the same in the pebble-layer ; about 8 feet ; resting irregularly on the sand below.
6. Fine light-coloured Thanet Sand.

1  
2

Figure 26. Cutting on the South Eastern (Lewisham and Tunbridge) Railway at Chiselhurst Station.



Scale, horizontal and vertical, 40 feet to an inch.

The section has been continued in the drawing to the former pit close to the southern end of the cutting, where the pebble-beds have scooped down to the Thanet Sand.

Blackheath Beds. Brown sandy pebble-bed, in great part changing into fine sharp light-coloured sand, with layers of clay at the southern end of the cutting; 10 feet at one part.

Woolwich Beds { 2. Clay with shells, a foot or two feet; cut off on the south.  
3. Clay, dark bluish-grey at top, the rest greenish-grey and ochreous; 5 or 6 feet.  
4. Black flint-pebbles in white sand; clayey at top (from the bed above); a foot to 1 1/2 feet; resting slightly irregularly on the next.

Bottom-bed { 5. Deep-green loam, with a few black and brown flint-pebbles; 2 1/2 to 3 feet; resting irregularly on the next.  
6. Bright green sand, mostly dark at the bottom, where it is sometimes hardened into stone; 15 inches or more.

Thanet Sand { 7. Whitish Sand; at the north 2 feet; cut off southward.  
8. Light-buff sand, ironshot at top.

Observed dip about 2°.

In the rather deeply-cut pond in the meadow near Hall's Farm both mottled and shelly clays may be seen, and the latter again by the lane on the north.

In the cutting north of the tunnel through Sundridge Park the shelly clay was touched at one part (see Fig. 41, p. 226). Through the north-eastern part of this Park the outcrop is very narrow, from the thinness of the beds and the steep slope of the hills.

The very small railway-cutting just south of the mouth of the Sundridge tunnel shows a somewhat uneven junction of the pebbly green sand with the light-coloured Thanet Sand.

The next cutting, close by southward, gives a fine section from the Blackheath Beds to the Thanet Sand. Although so deep it is on one side of the line only, owing to the sharp slope of the pebble-hill: into which however it has been cut back. Figure 25 is from a drawing made at two visits (March and April 1865) and is on the same scale for height and length.

In Camden Park about a foot of greenish-grey sand with pebbles (bottom-bed) was to be seen above the Thanet Sand at the clump of trees on the top of the hill just above the chalk-pit shown in Fig. 8, p. 116, and also in the old pit on the southern side of the small side-valley on the east. A pond more to the south is in the clay shell-beds, which also occur above the houses at the southern side of the park (1860). The lower of two large tanks at these houses showed 10 or 12 feet of drifted clay, loam, sand, pebbles and shells over Thanet Sand; the higher one showed a little of the same, with the bottom-bed beneath. On this (the eastern) side of Camden Park each bed makes a distinct, though very small feature, the pebbly bottom-bed forming the top of the hill just above the chalk-pit, and the shelly clay rising slightly above it. At the brickyard on the other side of the road to Bromley the clay worked was yellow and perhaps forms part of the bottom-bed, which seems to be very clayey in places hereabouts. In a garden a little higher I saw shelly clay and on the common at top of the hill brown and yellow sand under the Blackheath pebble-beds.

In Bickley Park a small but important railway cutting showed a slight unconformity between the Woolwich and the Thanet Beds, and a greater one between the Oldhaven and the Woolwich Beds. Figure 26 is from drawings of the western side made at two visits (1865, 66) the work having been left unfinished for some time.

The slight but steady unconformity between the Woolwich and the Thanet Beds is shown not only by the gradual cutting off of the bed 7, but also by the occurrence of traces of mollusc-borings in the top of the Thanet Sand, which are filled with the green sand from above.

The above note was taken before the line was finished, and the site of this cutting is now for the most part occupied by Chislehurst Station.

There is a strange irregularity in the occurrence of the beds hereabouts, the higher ones coming down sometimes to a lower level than the lower ones have near by. Just above, and nearly 50 yards from, the station a cutting, on the western side of the road, for the roadway to a new house (1870) is in Woolwich Beds, the shelly clays and the underlying green sand being both shown, and at bottom the Thanet Sand. The house itself, on high ground, is on the shelly clays, but just below it (and a little further up the road) is a pit in the Blackheath pebble-bed which goes down about to the level of the junction of the Woolwich and the Thanet Beds in the roadway.

Eastward there are many signs (in ponds and ditches) of the shelly clays, which rise up northward toward Chislehurst, and throw out water from the Blackheath Beds.

#### *Eltham.*

From Middle Park, just south-west of this village, an outcrop of the Woolwich Beds runs eastward for about  $2\frac{1}{4}$  miles, and may indeed possibly join on by a mere line, along the course of the brook between Coldbath and Gobylands Woods, to the narrow outcrop on the east. Its southern boundary is at a low level, except at Mottingham, but northward the beds rise up, with the ground, until they are capped by the overlying Series on the hill-



top, in the village of Eltham, &c., where the dip changes to the north.

In making the sewer along the high road blue clay with shells was found on the slope westward of Eltham Church, the Blackheath Beds coming on higher up eastward (see p. 229).

There are many surface-signs of the shelly clays, in fields and in ponds, and sand also occurs; the former are especially to be seen at the western and broader part, where the beds dip westward under the higher formations in the lower ground. This dip is well shown by the only good section in the inlier at the time when it was mapped, which I saw at its best, and of which a drawing is given in Fig. 27.

Although naturally there are plenty of signs of disturbance in an inlier I could see no evidence of the fault marked on Mr. Mylne's map, but was able to draw the boundary-lines and to account for the inlier without the aid of actual disruption, which however may occur somewhere here.

MR. J. S. GARDNER says "Mr. E. S. Dewick informs me that a bed of leaves was cut through fourteen years since by a railway excavation at Mottingham".\* Probably this cutting is the section in question, and the beds yielding the leaves would be l and l', the representatives of the Lewisham leaf-bed.

#### *Valley of the Wandle.*

MR. J. LUCAS, in noticing a series of wells in the Wandle Basin, says:—"All these borings traverse the London clay and underlying plastic clays, except, perhaps, five at Tooting, which after passing through gravel, come at once into mottled clays, or Woolwich and Reading beds, a fact which is here recorded for the first time. From this we learn that an anticlinal arch in the strata runs through New Wimbledon and Tooting in a north-easterly direction, to Peckham. It is partially dome-shaped, attaining its greatest elevation at Tooting Graveney. . . . There are two synclinal troughs accompanying this anticlinal, having parallel axes and situated, one on the north and one on south of it. The one on the north attains its greatest depression on the area immediately north of Garratt."† No details of the wells in question, nor any other evidence being given, the statement can only be made on its author's authority. Any uprise of Woolwich and Reading Beds here must be in the form of an inlier, surrounded on all sides by London Clay, supposing the tract to be bared of gravel.

#### *Down the Northern Side of the Valley of the Thames, from London to the Valley of the Lea.*

On the Middlesex side of the Thames the formation occurs next under the alluvium, &c. of the Isle of Dogs.

At the dock-gates of the new Millwall Docks the Lower London Tertiaries were found beneath the gravel. I saw a heap of green sand with flint-pebbles, (mostly brown) which came from a depth of about 35 feet below high-water-mark, and which without doubt belong to the "bottom-bed." Below this was green [Thanet] sand, and quite close to the river a little pea-gravel, partly hardened into pudding-stone, was found next above the "bottom-bed." I saw a piece of this stone, which belongs to the Blackheath Series. (See also *Borings, post.*)

\* Monogr. Brit. Eoc. Flora, *Palæontograph. Soc.* 1879, p. 10.

† *Journ. Soc. Arts*, vol. xxv., no. 1,277, pp. 600, 602. (1877.)

*Stratford.*

At Stratford there seems to be a slight uprise along the valley of the Lea, which results in bringing up the Woolwich Beds from beneath the surrounding London Clay; but as the surface consists entirely of a gravel-flat bordered by an alluvial one, nothing is to be seen. The evidence therefore is given mostly by wells; thus at the Great Eastern Railway Station there is no London Clay beneath the gravel, whilst at the Brewery, a third of a mile or so north-eastward, there seems to be a little (see Well sections, *post.*) Of course the boundary drawn for this gravel-covered outcrop is doubtful. It is quite possible that the uprise may continue southward for some way and that we may not have an inlier here.

The cutting on the main line of the railway is now turfed over, and shows nothing, but when it was made the gravel was found to be underlain by shelly sand, which, judging from the shells that were found, seems to belong, in part at least, to the Oldhaven rather than to the Woolwich Beds. The following short account of this cutting was published by DR. J. MITCHELL in 1839:—

"The eastern counties' railway passes near to the church, where there is a deep cutting, and on the east side of the bridge, on the road to Leytonstone, is a stratum of gravel ten feet thick, containing chiefly chalk flints. Below the gravel is a bed of sand, two feet in thickness."

"There is a second bridge [Waterlane Bridge] about 150 yards to the east of the first, and at this second bridge, and on the east side of it, in September, 1838, when the sections were fresh, the strata were to be seen more fully developed, being there 16 feet deep. The upper stratum is the gravel, below which is a yellow and greenish sand, and lower still is a mixture of sand and blue clay, being together the upper [lower] part of the London clay formation."

"In the bed of sand were many shells, most of them crushed and in fragments, and in some places in great abundance.—Occasionally the sand was consolidated into sandstone, and in the pieces of sandstone the shells were well preserved, and many very perfect specimens were obtained. Immediately under the sand is a mixture of sand and blue clay, in which are masses of shells, some crushed, others entire."

"In some cases the bed of crushed shells was two feet thick, in others, not six inches. There were also pieces of blueish sandy limestone, in which were masses of shells, and sharks' teeth were also found."

"The shells are recognized to be, *Rostellaria Sowerbii*, *Natica glaucinoides*, *Ostrea Bellovacina*, *Pectunculus brevisrostris*, *Cithæra Morrisii*, *Cardium Plumsteadianum*, *Melania iniquinata*, and a *Tellina*. The *Ostrea Bellovacina* is the same as *O. pulchra*, also called *O. variabilis*."\*

The section of this cutting, at Maryland Point, has been recorded by PROF. PRESTWICH,† from whose account the following is taken:—

[River Drift.]	Ochreous flint gravel, irregularly on the next; up to 7 feet. †
	Brown clay; † up to nearly 4 feet.
	Clayey green sand; about a foot.
	Yellow and ochreous sand; about a foot.
London Clay	Yellow and ochreous sand, with flint pebbles and many fossils; sometimes calcareous concreted masses; about a foot to 2 feet; irregularly on the next.
	Brown clay, dark grey clay, and yellow clay, together about 4 or 5 feet.
Woolwich	Yellow sand, 5 feet.
and Reading Beds.	Mottled clays, not exposed in the cutting.

\* *Mag. Nat. Hist.*, ser. 2, vol. iii. p. 250.

† *Quart. Journ. Geol. Soc.*, vol. vi. p. 262. (1850.)

In the excavation for the foundations of a house just north of the church (in High Street) I saw, in 1872, London Clay capped by made ground and a little gravel.

MR. A. P. WIRE has drawn attention to the uprise of the Woolwich Beds at Leyton.\* He says "in excavating recently for the new deep sewer in Union Lane, Leytonstone, the men cut across a bed of dark . . . clay, . . . full of fragments of shells . . . By far the larger quantity of these are *Cyrena cordata* in all stages of growth . . . The bed has from 12 to 17 feet of gravel lying over it." A further examination resulted in the following list of shells:—

Cerithium, sp.	Planorbis, sp.
Hydrobia Parkinsoni.	Valvata, sp.
" Websteri.	Cyrena cordata.
Melania, sp.	Ostrea, sp.

"In addition to these shells there were found small masses of iron pyrites, pieces of wood and vertebrae of fish."

MR. WIRE tells me that the sewer cut through these beds for only a few yards, at a spot about a quarter of a mile east of Leyton Station, and that blue [? London] clay was found (under the gravel) some yards to the west. This shows that the uprise goes a little further north than was thought before, that the shell-beds are present, and that the Blackheath Beds are absent.

*Down the Northern Side of the Valley of the Thames, below the Valley of the Lea.*

Below the Lea the Lower London Tertiaries are hidden under the broad spread of alluvium for some miles, and we see nothing of them, on the northern side of the Thames, till reaching Wennington.

The narrower outcrop of the Woolwich Beds then follows that of the Thanet Sand from Wennington eastward to beyond Stifford, when it widens in its further course to Stanford-le-hope, being hidden by gravel just at first, and again to some extent east of Aveley.

At Stifford the Woolwich Beds cross the valley of the Mardyke, and beyond the village the gravel of the hill-top hides everything for some way, and makes the boundary doubtful.

Southward from Stanford-le-hope the outcrop is hidden by the gravel, and then the beds probably stretch under the alluvium to the other side of the Thames at Halstow Marsh, without being covered by London Clay.

Along the northern bank of the small valley on the east of Aveley there are signs of the outcrop; shelly clay occurs by Hangman's Wood, the green bottom-bed was turned out from a ditch by the edge of the alluvium just west of Branard's Wood, and the shelly clays occur in the fields west of Stifford Bridge.

Down the lane a little north-east of Stifford church the following beds are shown, with a northerly dip of about 10°.

Gravel. (River Drift.)

Reading Beds	{	Clay up to a foot.
		Lignite and sandy clay, about a foot.
		Grey and brown sand with streaks of a lignite-like
		character, hardened into stone at top (in parts black).

The lignite occurs again by the edge of the alluvium just north-east, and the bottom-bed (green sand with pebbles) may be seen on the high road just below the cross-roads east of the church, and in the field on the other side of the little valley further east (re-mapped 1872).

\* *Trans. Essex Field Club*, vol. iii. ; *Proc.*, pp. iii., iv., lxxx., lxxxi. (1883.)



I am inclined to think that the boundary-line may have been drawn too far to the north, or else that there may be an outlier at West Tilbury, unless I am mistaken in the classification of the beds in the following section, along the road down the hill westward of the church:—

Gravel, the lower part very sandy (sometimes nothing but coarse light-coloured sand); partly false-bedded; the bottom cemented into a conglomerate by iron.

Bottom-bed of the Woolwich Series? Greenish-grey sand with a little clay, partly ferruginous; flint pebbles at the base.

Thanet Sand, of a finer grain.

On the road west of Wharton Hall there is, below the gravel, grey sand with clay, and lower down greenish clayey sand, which one might have thought to be the lower part of the formation.

MR. BRISTOW has supplied the following notes of sections at Mucking and Stanford.

"At my request MR. LOCKEY, engineer to the London and Southend Railway, had several shallow trenches made in the railway-cutting north of Mucking, but owing to the ground having been moved and to much earth having been brought there to supply the place of that which had slipped, a distinct exposure of the junction of the clay and sand could not be got. In the clearest section made the base of the cutting seemed to be in whitish or pale green sand, passing into bright ochreous yellow and then into ferruginous brown, which last was overlain by pale grey pipe-clay with a slightly reddish tinge and passing into a ferruginous brown clay, that bore every appearance of being London Clay [irregularly capped by gravel, north of the bridge]: here the sand was laid open to a depth of 10 or 12 feet, and the clay to about 5, but neither the bottom of the latter nor the top of the former was reached. At the foot of the cutting in other places there was bright yellow sand, and higher up variously coloured dark clays, all bearing a strong likeness to those of the Woolwich and Reading Beds. By the bridge over the line there is a whitish pipe-clay, with a carbonaceous layer, about an inch thick, resting on it."

"In the cutting to the north, near Hassenbroke, a pebble-bed (? belonging to the Oldhaven Series) about three feet or more thick, overlies yellow clayey sand with thin layers of tough yellow clay. Here MR. LOCKEY was kind enough to make a boring, on the northern side. It was carried down 18 feet through a pale olive-green or greenish-grey sand, drying to a paler tint, and at a depth of 15½ feet a few small flat and round black or blackish-brown pebbles were brought up by the auger. The sand is exposed in the cutting for about three feet above the bore-hole, making the whole thickness 21 feet, but the boring was abandoned before the bottom of the sand was reached, the point for which it was begun having been satisfactorily made out, namely that the sand was not Drift. It is very pure; composed of rather coarse grains of translucent quartz, being a sort of glass-house sand; and in the cutting it dries white, with occasional pale brownish layers."

"The sand beneath the gravel at Stanford-le-Hope is of an ochreous-yellow colour, with darker laminations. A good section of it was made between the Railway Inn and the King's Head, in a garden on the southern side of the street, where it was dug for building-purposes, for which it is well suited. No pebbles were noticed in it."

"The gravel has been stripped off over a great part of the village, which is built on the underlying sand; but the former may be seen in many places, and a large pit is dug through to the sand."

#### *Outlier.*

A little way up the lane about two-thirds of a mile west of Stifford Church a little of the green sand of the bottom-bed comes in between the gravel that caps the hill and the Thanet Sand. This patch may perhaps join on to the main mass on the east, but it is more likely to be cut off by the gravel (1872).

#### *Main Mass, Hundred of Hoo, Kent.*

Resuming our course along the main mass, the Woolwich Beds rise up southward from beneath the alluvium of the Thames on

the north of High Halstow, and very soon take a westerly course along the flank of the hills, and again sink to the level of the marshes south of Higham.

The spur stretching a little way westward from between Higham and Higham Street is in a slight trough, the northern side of which is for the most part hidden under the marshes.

South-eastward from Higham the outcrop turns southward and then south-eastward, running along the flank of the hills, out of our district, to the Medway near Upnor.

In a field less than half a mile north of High Halstow church there is, at the foot of the London Clay slope, a hillock formed by the outcrop of the Lower London Tertiaries. I saw this whilst it was being ploughed, and was able to note the following order of the beds:—

Sandy (at top).  
Shelly clay (a little way down the slope).  
Clay and sand (a little).  
Lignite-earth (a thin layer).  
Ferruginous clayey sand.

At Dolans, half a mile west of High Halstow, there is a bed of fragmentary and rubbly brown sandy ironstone over sand, and on the road just north-west this ferruginous bed is again laid open, and mixed with it is grey and red mottled clay with whitish marly patches, from below which light-coloured sand crops out. This last must overlie the bottom-bed, which is shown a little way down the road that turns north-eastward to Buckhold Farm, where it consists of flint-pebbles in grey sand full of dark grains, in parts cemented into a crumbling conglomerate.

The large railway-cutting through the hill east of Cooling Court gave a fine section, from the London Clay down to the Thanet Sand. From the westerly fall of the line and the slight easterly dip, the lowest beds were shown only at the west, the clay shell-bed sinking to the level of the line before reaching the eastern end. The London Clay, Oldhaven Beds, Woolwich Beds and Thanet Sand were seen to occur in even order, without erosions; but at the eastern end a mass of brown loam (? the wash of the hill) comes on, to a good thickness. The succession, which was noted whilst in charge of an Excursion of the Geologists' Association,\* is as follows, some particulars having also been observed by MR. W. H. SHRUBSOLE, who sent his notes to me, and who says that the cutting is 35 chains long and 35 feet deep:—

Brown London Clay, without the usual basement-bed, or pebbles; 8 feet seen, near the eastern end and on the southern slope.

Oldhaven Beds,   
    ? 10 feet.   
(MR. SHRUBSOLE makes only 3).   
    { Fine buff false-bedded sand, with some patches of fossils (Turtle, pieces of carapace, *Lamna*, teeth and vertebrae, small bones, *Melanopsis*?, *Natica*, *Cardium plumsteadense*, *Corbula*? and *Pectunculus*); up to 8 or 10 feet.   
    { Pebble-bed, from 6 inches up to 3 feet (so thick at one part only).

Woolwich Beds.   
    { Light-coloured sand, with incipient concretionary structure, and partly ochreous; about 7 feet. MR. SHRUBSOLE divides this into yellowish sand, with tubular concretions, 2 feet, and brown sand, 5 feet.   
    { Clay shell-beds (*Cyrena*), about 3 feet.   
    { Sharp grey and pale greenish-grey sand, of good thickness; traces of peaty matter in the upper part. MR. SHRUBSOLE notes this as mottled loam, 5 feet, and purplish lavender-coloured sand, seen to 3 feet, beyond which his note does not go.   
    { Signs of a pebble-bed, at the shallow western part, and at the western end that bed, only a few inches thick, and consisting of very small flint pebbles, was seen over the next.

Fine soft Thanet Sand, a few feet seen.

\* See *Proc. Geol. Assoc.*, vol. vii., no. 3, pp. 189–191 (1881).

The small cutting just eastward was not finished at the time of my visit (June, 1881), but showed sand, probably belonging to the Woolwich Beds.

A little N.E. of Perry Hill there is sand, and half way between that place and the road on the west, the green bottom-bed was seen, and in the neighbourhood of Oakly the shelly clays appear.

I was told that in a well, less than 20 feet deep, at the farm about 300 yards north of the road by the "Tumulus" (marked on the old Ordnance Map) the shell-bed was found.

At the railway-cutting about a mile westward of Higham Station a clay shell-bed crops out near the eastern end, and a little to the west is capped by a more sandy shell-bed (see p. 235). By the canal just east the shelly clays are again to be seen, and PROF. HUGHES noted the following succession of beds along the canal-bank :—

	Alluvium ? (on the north).
Woolwich	{ Greenish-grey and rusty sand.
and	{ Lignite in patches.
Reading	{ Sand, the top part dark brown.
Beds.	{ Rusty loam.
	{ Clayey loam with pebbles.
Thanet Sand.	

The shelly clays may also be seen in the roads northward of Higham Street.

The cutting on the road about a quarter of a mile north of the tunnel-mouth at Higham Station is much overgrown, but yet gives a fair section, as below :—

	{ Sand (at the highest part, north).
Woolwich Beds.	{ Bottom-bed. Green and green-grey sand, some beds clayey, others gritty, with a few layers of pebbles (mostly very small), about 9 feet.
Thanet Sand (up to a little north of the cross-roads).	

In a ditch along the road about three quarters of a mile south-east of Higham Church light-grey sand was found: eastward this was darker and more clayey and capped by a little shelly clay.

### *Outliers, Kent, east of the Cray.*

Between the main outcrop just described and the Valley of the Cray there are a number of detached masses.

The three spurs south of Bexley belong to two outliers, in Jorden's (or Joyden's) Wood, the chief part of which is in the map to the south, and they may therefore be left for the Memoir on Sheet 6. On the north the eastern patch almost joins on to another outlier, in which the road-cuttings about a third of a mile south-east of Bexley Church show the Thanet Sand, capped by grey and greenish-grey clayey sand with a few pebbles, above which there are signs of clay. This outlier is cut off on the north by gravel, at the edge of which however there are sometimes traces of the pebbly bottom-bed, so that perhaps there are patches of this formation under the gravel.

### *Swanscombe Outlier.*

The large detached mass of Thanet Sand southward from Swanscomb (see p. 119) is capped by two outliers of the Woolwich Beds, and although the chief of these is not wholly in our district, but spreads southward into Sheet 6, it is better to describe the whole at once.

At Mount's Wood there is a patch of the Woolwich Beds, partly capped by gravel, and without sections, but the pebbly bottom-bed is shown in the field on the north.

The far larger mass, which caps the Thanet Sand over a great part of the outlier, is of a straggling shape, and its boundary much

hidden by wood. There are however two road-cuttings that give fair sections, whilst the shelly clay and the pebbly greensand are often to be seen at the surface, in the lanes, fields, and woods.

Down the road through Darent Wood to Lane End, the following beds are shown :—

Woolwich Beds.	{	Buff and light-coloured sand, with a few small pieces of crumbling sandstone; probably about 10 feet. Bottom-bed. Green and grey sand; partly ochreous or iron-stained; with pebbles, which are very plentiful in the upper part; about 8 feet: ends just above the edge of the wood on the south of the road.
Thanet Sand: the base-bed cropping out just below the wood on the north of the road.		
Chalk.		

On the road from Betsham to Green Street Green the deep cutting down the hill to the latter place shows :—

Woolwich Beds.	{	Shell-beds { Clay with shells. Bluish-grey clay without shells. Sandy shell-bed. White and black peaty sand. Sand, yellow at top; then mottled with red; then yellow-stained; then grey, with a few thin seams of clay; 15 or 20 feet. Bottom-bed. Clayey greensand, ochreous and hard in parts, with a few pebbles (a bed of them at the bottom a foot thick, and iron-stained); about 2 feet.
Thanet Sand.		

The like is shown (the bottom-bed being less pebbly) from the cross-roads down towards Betsham, but the section is not so clear. After the Woolwich Beds have ended off there is often loam with drifted Woolwich shells over the Thanet Sand.

In a field on the southern side of the same road, about a third of a mile south-west of Betsham, there are blocks and pieces of iron-sandstone, derived from the Woolwich Beds, which come on just above. Brown sand and iron-sandstone may be seen on the other side of the road, by the western edge of the wood.

At the corner of an orchard about half a mile westward of Betsham, and near the road to Stonewood Farm, a junction of the Woolwich and the Thanet Beds was shown by a cutting along a hedge down the hill southward, the succession being :—

Woolwich Beds	{	Sand. Clayey greensand, 2 or 3 feet. Irregular bed of iron-sandstone, from 2 to 6 inches. Grey and yellow mottled clayey sand, about 2 feet. Iron-sandstone, with pebbles (in parts a loose pebble-bed), more than a foot.
Thanet Sand.		

This section is remarkable for the greensand not being at the very bottom of the series, but being underlain by sand and iron-sandstone: in this case however there are no pebbles in the greensand. Along the road shelly clay occurs at and near the top of the hill, with sand lower down.

In a field by the obtuse angle of the road just southward of Stonewood Farm a shallow ditch (fresh in 1861) passed through the following beds, in descending order:

Brown clayey sand.  
 Light-coloured sandy clay, partly a sort of pale grey pipe-clay.  
 Clay with shells.  
 Clay and sandy clay.

From Swanscomb westward for about half a mile a stiff clay-drift hides the junction of the Woolwich and Thanet Beds.

At the northern edge of Swanscomb Park Wood the shelly clay occurs in the field, and in hot dry weather is very deeply cracked. There seems to be sand below.

The bottom-bed crops out near the southern end of the lane leading to the wood, half a mile south-west of Swanscomb Church, where it consists of brown, yellow, grey and greenish sand, more or less clayey, with pebbles and ironstone. The Thanet Sand is shown below.

#### *Gravesend.*

Windmill Hill consists of a small outlier of the Woolwich Beds with two wee cappings of the Blackheath pebble-bed.

On the road just east of the windmill there is, at the highest point, roughly laminated clay with a few poor impressions of shells and of small selenite crystals, below which (southward) is sand.

At the eastern end of the small crescent close by (east) the following were shown :—

Blackheath pebble-bed, a foot to 3 feet or more, lying irregularly on the bed below.

Woolwich Beds	{	<p>Roughly laminated clay; the upper part grey, the lower brown, about 2 feet.</p> <p>Sand. Lower down (eastward) there is a layer of pebbles in sand; and still lower a foot or so of a pebble-bed, which may perhaps be a slipped mass of the Blackheath Series.</p>
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At the back of the houses on the south-west of the hill was a larger section, showing the continuation downward, which must have been a very good one before it was overgrown.

Woolwich Beds	{	<p>A little of the laminated clay (as noted above) at one part.</p> <p>Bedded light-coloured sand, in great part with dark grains; very many thin layers of iron-sandstone and of clay throughout, giving the whole a laminated look; also two interrupted layers of pebbles; and a few scattered pebbles at the bottom; 20 feet or more thick; almost into the next.</p> <p>Bottom-bed. Black flint-pebbles, mostly small, in sand with green grains; altogether of a greenish tint; over 2 feet.</p>
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Thanet Sand. The junction at the same level at all the spots where it is shown.

Southwards there is drifted loam, and the pebbly bottom-bed runs out along the spur to the south-east.

For the following two sections, noted in 1748, by a very acute Swedish observer, PROF. P. KALM, I am indebted to MR. J. LUCAS, who has allowed me to use his manuscript translation.\* They probably refer to pits long since closed. The author says that "on the southern side of Windmill Hill . . . was a large pit from which they took sand. Here we saw what the hill . . . consisted of, and reckoned the same . . . as follows, beginning at the top." The section is given in great detail, and is here condensed :—

Soil, the lower half yellow and mixed with fine sand; 2 feet.

Light-grey fine sand; here and there with ochre or rust-spots (in the upper part); with light-ochreous-coloured sand, half an inch thick, in waves, in the middle; and with an inch of rust-coloured, or dark ochre-coloured, sand at the bottom; over 3 feet.

Fine very light-coloured sand, with half an inch of ochre-coloured sand 2½ feet down; "to the bottom of the pit, and who knows how far down?"

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\* *En Resa til Norra America* . . . . tom. ii., p. 50-52, *Stockholm* 1756.

"Higher up on the hill was another sandpit, the bottom of which was higher than the top of the foregoing. There the beds were in this order" (greatly condensed):—

	FEET.
Soil, mixed with fine brick-coloured sand and small pebbles	1
[Blackheath Beds]. Black flint pebbles, mostly the size of marbles.	
No angular stones seen	2½
Ochre-coloured fine sand	2½
Alternations of thin layers of fine white sand and of ochre-coloured sand with thinner layers of grey clay	about 2½
[Woolwich Beds, 20 feet.]	
Fine white sand, with some thin layers of a light-grey and of an ochre-colour	8½
Light-grey sand, full of rust-spots	2
Ochre-coloured sand	3
Pebbles, with light-yellow sand	1½
Fine white [Thanet] sand	4

If the classification given in this last is right, as there is little reason to doubt, the former section must have been wholly in Thanet Sand. The author concludes with remarks showing his possession of two qualities essential to the field-geologist, caution in drawing a theoretical conclusion, and power in drawing a stratigraphical one. "Whether all these Strata came into their present shape at the Sin-flood, or any other occasion, I leave to others to divine. The whole of this high sandhill most probably stands upon solid Chalk, because all the plain round about consists of bare Chalk."

In the Hundred of Hoo, there is a very small outlier of the pebbly bottom-bed, which may be seen above the Thanet Sand in the lane going northward from the road about halfway between High Halstow and Cooling.

## CHAPTER 12. LOWER LONDON TERTIARIES (READING BEDS).

### NORTHERN OUTCROP.

#### *South of the Thames to Windsor.*

Crossing over now to the northern outcrop we may trace it from the western edge of our district.

Here we have to deal with a simpler set of beds than on the south, no trace of the shelly clays having been found, and no fossils, except for oyster-shells at some places in the bottom-bed: we have only mottled clays, sands, and occasional pebble-beds. Moreover the upper and lower divisions of the Lower London Tertiaries are absent, and the Reading Beds alone separate the London Clay from the Chalk.

#### MAIN MASS.

On the western side of the Loddon, the junction of the Reading Beds and the Chalk is mostly hidden by gravel, but its position is approximately shown by a swallow-hole about a quarter of a mile S.W. of Chorvil Farm.

On the other side of the Loddon these beds are again hidden by gravel, but N. and N.E. of Ruscomb the gravel ends off, and the Reading Beds are at the surface.

For more than a mile eastwards from Stanlake, towards St. Laurence Waltham, the boundary-line is hidden by the alluvium of what was once Ruscomb Lake, and then runs roughly parallel to the Great Western Railway, by Shottesbrook and White Waltham, to Shoppenhangers Farm, near Maidenhead; but there are no good sections of the Reading Beds in this tract of country.

Eastward the boundary-line is altogether hidden by the Valley Gravel, which southward of Bray spreads over to the London Clay, so that the line of outcrop of the Reading Beds is there hidden also.

On the map the boundary-lines of the Reading Beds and of the London Clay have been shown as running eastward, by Dorney and Boveney, to Windsor, and thence, turning north-westward at Datchet, as running respectively to Burnham and Farnham Royal. It was felt however that, in the absence of any evidence, from wells or borings, the above course, beneath the flat of gravel and alluvium, was very doubtful, and in the earlier description of the map it was said, of the Reading Beds at Windsor, "it is possible, that they may here occur as an inlier," and the Chalk there was noted as probably an inlier.\* In a later Memoir the subject was again

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\* *Memoirs of the Geological Survey* . . . "The Geology of Parts of Middlesex," etc. pp. 13, 8, (and 11, 27) 1864.

alluded to;\* but nothing more could be said, no further evidence having occurred.

Ten years later MR. J. L. LOBLEY described a boring "near the village of Datchet,"† (but without giving the precise site) which shows that too great an extension has been given to the Chalk and to the Reading Beds on the Map, 20 feet of London Clay having been found next beneath the gravel. (See *post* for details.) That our author is right in concluding that this "would seem to point to the existence of a fault between Slough and Windsor" is doubtful, as also is the further conclusion that "the fault must be very near to the boring, as the Chalk is mapped at a furlong distance." It has been shown above that I was by no means inclined to depend much on my own mapping hereabouts, and I would sooner admit a fault in the mapping than in the beds, without further proof.

The most important evidence however for concluding that the outcrops of the Chalk and of the Reading Beds at Windsor form an inlier, surrounded on all sides by London Clay, is new and now published for the first time.

The Grand Junction Water Company have lately made two trial-borings, one at the eastern part of Dorney Green, or Common, and the other at the southern. In the latter, where Reading Beds have been mapped as next under the gravel, there is London Clay, to the thickness of 20 feet; and in the former, where Chalk had been guessed to underlie the gravel, the London Clay is 30 feet thick.

These borings clearly point to the conclusion that the boundary-line of the London Clay runs somewhere through Dorney to Farnham Royal, whilst that of the Reading Beds may run somewhere through Bray to Burnham. For any approach to exactness however further evidence is needful.

For details of the borings, which will be given further on, and for other information bearing on the subject, we are indebted to MR. A FRASER, Engineer to the Grand Junction Water Company.

In the railway-cutting east of Twyford Station variously coloured clays and sands are shown beneath the gravel. Clay seems to be more abundant at both ends of the cutting; sand in the middle part. At one place, near the middle of the cutting, there are some small pieces of hæmatitic iron-stone.

At the brickyard N.E. of Ruscomb there is mottled clay, and the green clayey sand of the bottom-bed may be seen in the fields to the N.E. In the large pit west of the church I saw (in 1860), under the gravel, a few inches of mottled clay, with brown laminated sand below, seven feet of the last being shown. In a well at some cottages near by, on the other side of the railway, the Chalk was not reached at a depth of 40 feet, whilst in another, close to the church, that rock was touched at a depth of about 30 feet: in both cases clay was in excess.

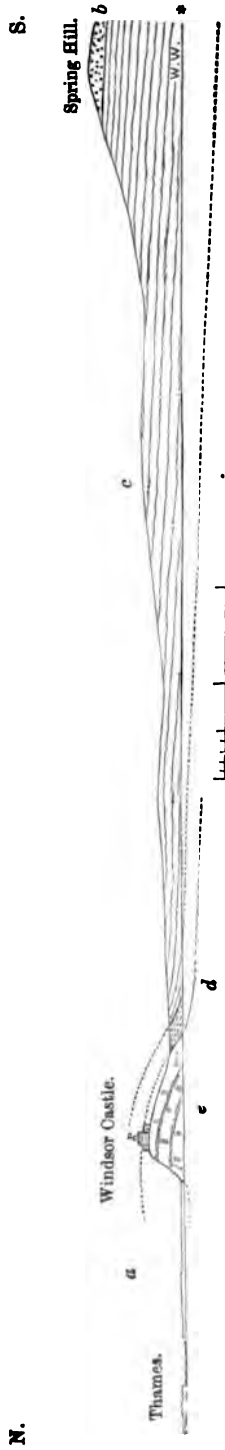
At Stanlake, south of Ruscomb, in a well in the farm-yard close to the house, 23 feet of clay were found above white sand, the latter yielding plenty

\* Memoirs of the Geological Survey, vol. iv. pp. 53, 191. (1872.)

† *Proc. Geol. Assoc.*, vol. vii., no. 7, pp. 391-395 (published 1883).



Figure 28. Section from the Thames north of Windsor Castle to Spring Hill.



Horizontal Scale 2 inches to a mile. Vertical Scale about four times as great (an inch = 660 feet).

a. Gravel of the Thames. b. Lower Bagshot Sand. c. London Clay. d. Reading Beds. e. Chalk. \* Approximate level of the Thames.

of water. At the highest part of the road between Stanlake and Hinton House there is mottled clay; and in the lane, about half a mile a little N. of E. of the latter place, sand is shown.

Mottled clay occurs by the meeting of the roads more than half a mile S.W. of White Waltham Church.

At Paley Street the channel of the Bray Cut must have shown a good section when clear. It is now much overgrown, but I was enabled to make out the following succession (in 1869), the upper beds occurring on the south, and the lower on the north:—

		Ft. In.	
London Clay.	Basement-bed.	Brown clay with a few pebbles at the bottom.	
		Layer of scattered pebbles.	
		Whitish loam with shells -	1 4
		Sandstone with shells (chiefly of <i>Ditrupa</i> ) -	0 2
		Grey sand, with shells of <i>Ditrupa</i> just at the bottom -	2 6 or more
		Brownish clayey sand, passing into the bed below -	1 0
		Grey sand, rather more clayey than that above, with a layer of <i>Ditrupa</i> -shells close to the bottom, and a few shells below this layer -	1 0
Reading Beds.		A little pale grey and brown clay.	
		A little red mottled clay with race.	
		Light-buff and mottled sandy clay, with blocks of sandstone (sometimes 2 feet thick, sometimes with holes like those of a small boring mollusc ?), 5 feet and upwards.	
		Mottled clay, hard at top.	
		Sand, blackish at top, a few feet shown north of the road.	

At one part the sandstone in the loam forms a continuous bed, two feet or more thick, which crops out as a ledge in the watercourse.

MR. POLWHELE notes that "in the lane about 200 yards N.W. of Shoppenhangers Farm there is mottled clay." East of this the high terrace of the Thames gravel hides the Reading Beds; but at the junction of the roads half a mile west of Bray Wick there is some mottled clay, and there are signs of the like being present, below the gravel, just west of the same place.

At Stud Green, on the south, says MR. POLWHELE, "the pit in the brick-yard gave the following section, according to the workmen:—

Brick-clay, sandy; 5 feet.  
Bands of sandstone; a foot.  
Brick-clay; 9 feet.  
Mottled clay and blue clay.

"The *Ditrupa plana* was found in the basement bed of the London Clay." It is hard to say where is the division between the London Clay and the Reading Beds here, but I should think that only the first two beds belong to the basement-bed of the former.

#### INLIERS.

The outcrop of mottled plastic clay, along the little valley southward from Moneylow Green, nearly four miles south of Maidenhead, seems to be surrounded on all sides by London Clay, though it was at first mapped as joining on to the main outcrop a mile to the north. The clay is there shown in the lanes and along the stream, and at one part of the latter it contains some sandstone with small tubular holes.

At Windsor this formation again crops out. The Castle is on bare Chalk, whilst to the south the London Clay comes on, and a section across it would be as in Fig. 28. The boundary-line of the Reading Beds here is of course very doubtful.

Through the kindness of my former colleague, MR. F. DREW, of Eton College, I have been favoured with a tracing of a map, on a large scale, on

which Mr. LUNDY had laid down the boundary-line of the Reading Beds through Windsor, from information collected from seeing openings in the streets during many years. Mr. DREW, who has verified much of the information, says that this line "may be taken with confidence to show within a few yards the junction of the Chalk and the Tertiary beds." According to this the Reading Beds have a slight further extension than has been shown on the Geological Survey Map, the boundary-line running along High Street, from Sheet Street to Castle Hill, and then turning westward, just north of Peascod Street.

The following evidence of the presence of the Reading Beds at Windsor was noted in 1869:—Close to the northern end of Sheet Street the excavation for the foundation of a house, on the western side of the road, laid open grey and yellowish clay; whilst a larger opening lower down on the other side, 60 yards and more from the top of the street, was in red, blue, and variously coloured mottled clays.

#### OUTLIERS.

On the high flat-topped chalk-country between Henley-on-Thames and Wargrave on the west, and Maidenhead and Cookham on the east, there are some well-marked Tertiary outliers, one of which is the finest that I know of on the northern side of the London Basin.

When this neighbourhood was first surveyed a small outlier at Park Place escaped my notice, perhaps from the want of sections at the time: its presence was however detected by my colleague Mr. F. J. BENNETT in 1869, in re-surveying for Drift. He notes that brown and light-coloured sand "is worked to a depth of about eight feet in a pit about a quarter of a mile north-eastward of the house, and plastic clay is found on the south: it has been worked for brick-making and seems to lie irregularly." At the kiln, at the southern end of the outlier, there is a little of the greenish loamy bottom-bed over the chalk.

#### *The Wargrave Outlier.*

Although this is so large and important, yet there is no place of any size on it, and I have therefore named it after the neighbouring village of Wargrave. It consists of a wide-spreading mass of the Reading Beds with two thick outliers of London Clay, the latter forming hills that are most striking objects many miles off, the more so as they are thickly wooded up to the top.

The most westerly point is nearly a quarter of a mile west of Chamberlain's Farm on the hill east of Wargrave Marsh. From this place the boundary-line follows the contour of the ground, keeping pretty much to the same level, by Cockpoll Green and Warren Row to near Hall Place. Then trending southward to Littlewick Green, and thence south-westward by Knowl Hill and Bear Hill to Castle Farm, more than half a mile N.E. of Ruscomb, it gradually reaches a rather lower level, and then rises again N.N.W. to our starting-point. The general dip would therefore seem to be S.S.E. at a very small angle.

The shallow cutting in the lane down the hill from Chamberlain's Farm to Crazy Hill shows the bottom-bed (about five feet thick, clayey throughout, with a few green grains towards the base) resting on the Chalk.

Another junction is shown at the brickyard higher up the little valley, and just south of Crazy Hill, the following being the order of the beds; the section did not allow of my measuring their thickness:—

Reading Beds { Light-coloured sands.  
Mottled clay.  
Bottom-bed, for the most part roughly laminated clay.

Chalk.

There is a swallow-hole in the valley here, and higher up southwards there was, in 1858, a small pit, showing rather more than ten feet of light-coloured sand.

Just S.W. of Cockpoll Green, at which place the Chalk crops out to the surface, is another swallow-hole; and the bottom-bed is shown in the road to Dean Place (a little below the cross-roads), and in a swallow-hole at Pudder's Farm.

At Warren Row there are swallow-holes within the boundary-line, at its re-entering angles, and I have seen water flowing quickly and in fair quantity into some of them. South of this place there is sand; and near the road, a little westward of where the lane from Hurley Bottom joins it, I saw the following section, in 1859:—

Reading Beds { Mottled plastic clay.  
Bottom-bed { Bluish-grey clay, roughly laminated by thin sandy layers, about 4 feet.  
Sand with green-coated flints, about a foot.

Chalk.

Up the hill further east, by the road turning off to Knowl Hill, and just below where the London Clay comes on, there is sand, as also in the fields S.W. of the farm on the south of Prospect Hill.

At the road-turning westward of Hall Place is a swallow-hole, and another in the wood more than half a mile south of that house.

Along the lane above Chalk-pit Farm there is clay, whilst by the high road at and west of Littlewick Green, and in a chalk-pit farther towards Knowl Hill, there is sand. At the brickyard on the north clay again occurs; but I could see no clear section; and a pit, more than 15 feet deep, about a quarter of a mile S.W. of the church at Knowl Hill, is in light-coloured sand with some of a bright crimson hue, and a little pale grey clay.

The thin spur that reaches southward from this part has a doubtful boundary; but the railway-cutting at Waycock Field shows some of the green bottom-bed above the Chalk.

The pit in the brickyard north of Bear Hill gave the following section, in 1859:—

London Clay { Brownish clay.  
Basement-bed. Brown and grey loam with layers of clay; about 6 feet.  
Reading Beds { Light-coloured sand; many feet shown, but not bottomed.  
Mottled clay; shown at a lower level.

In the field about a third of a mile nearly S.W. of Piggott's Farm, the green sand of the bottom-bed is turned up by the plough, whilst at a higher level there is clay.

West of Castle Farm,\* this large outlier is not far separated from the main mass N.E. of Ruscomb. I was told that in sinking a well at Castle End Farm chalk was touched at a depth of 14 feet, and that oyster-shells were found above that rock. At the farm there is clay; just west, and also at the cross roads on the north, sand.

At Hare Hatch is a swallow hole, another at the re-entering angle of the boundary-line between that place and Bear Hill, and another about a quarter of a mile to the north-west of the second.

The spur of clay just north of the first place escaped notice at first, but was added in a later edition of the map (Sheet 7).

\* A farm at the most westerly point of the outlier, destroyed since this account was first published (in the Memoir on Sheet 7, 1864).



Hill the mottled clay causes a flow of water from the overlying gravel. In a gravel-pit in a field on the south of the road, and no great way west of the railway-station (on the branch line), mottled clay is found at the bottom, and on the western side of the cutting at the station the green bottom-bed is shown between the gravel and the Chalk.

On the southern side of the Great Western Railway, at the 25th mile-post, there is a small outlier not reaching as far as Shoppenhangers.

*Outliers, between the Thames and the Loudwater.*

Near the southern corner of East Wood, three miles west of West Wycombe, there was, in 1858, a pit showing a depth of many feet of light-coloured sand. As the Chalk comes to the surface on all sides and at as high a level, or is capped by Drift only, the sand must be merely a large pipe in that rock.

At Dell's Farm, about half a mile to the south-east, I saw some brown, red and blue mottled clay, and along the road a little to the west some light-brown and whitish sandy clay and clayey sand. Some of this may belong to the Reading Beds, but it did not seem safe to map it as such.

Rather more than a mile to the south, at Cadmore End, there is some sand which may also belong to this formation; but it is so mixed up with gravel that this is doubtful.

*The Lane End Outlier.*

This strangely shaped mass of the Reading Beds radiates in three directions from a central part near Lane End; on the N.W. over Cadmore End Common; on the S.S.W. to Moor's Common, where the beds are much disturbed; and on the E. to Park Hill; and it is capped in many places by London Clay (see p. 252). Each of the three spurs is much broader towards the part away from the centre; so that the outlier is, as it were, made up of three masses joined on by narrow strips to a fourth and central mass.

At Cadmore End Common there is sand; but the boundary-line is hidden by brick-earth; and on the S.E. the sand is covered by gravel.

On the southern side of the high road a little west of Bolter End there was (in 1870) a pit about eight feet deep (my colleague Mr. J. H. BLAKE, the year before, noted a depth of about 16 feet) in a sandy pebble-bed, *the pebbles being all flints*, and the whole looking just like the Eocene pebble-beds of other and distant parts. When this district was first surveyed I saw no such section, and, knowing of no mass of pebbles in the Reading Series in this or in any of the neighbouring outliers, concluded that all the pebbles were from the Drift. This local bed, which makes a well-marked hillock, is of interest, as being the only instance of such a deposit in the Reading Beds within a considerable distance, and it will account for the very pebbly nature of some of the neighbouring brickearth. Near Bolter End there is again sand, and on the northern side of the turnpike-road between this place and Lane End are two swallow-holes; the boundary being marked also by the rise of the ground.

My colleague Mr. R. H. TIDDEMAN found (in 1868) some leaves in the Reading Beds, close to the Parsonage.

On the common just west of Lane End, by the side of the high road, some small pits showed the following beds (in 1859):—

London Clay.	{	Stiff brown clay, with <i>Septaria</i> and broken fossils.
	{	Basement-bed. Brown loam with layers of clay; green grains in parts; at the bottom a few flint-pebbles of various sizes.
Reading Beds.	{	Alternations of laminated greenish clay and brown sand, a foot or more thick.
	{	Light-coloured sands.

At Lane End there is sand, and just to the east the outlier is almost separated into two.

Around Park Hill no artificial sections were seen; but the boundary-line is marked by many swallow-holes, in some of which the green bottom-bed is shown above the Chalk, and by the sharp rise of the ground.

On the common S.W. of Lane End there are many pits in the sand of the Reading Beds, in some of them capped by the loamy basement-bed of the London Clay.

Further in the same direction the Reading Beds continue down the slope of the hill, instead of ending off as one would expect, showing that they have been here affected by some disturbance.

On the common below Stockwell both sand and mottled clay have been found, and it is possible that a spur of sand may stretch over to Moor Farm. At the eastern side of the common a few feet of the Reading Beds were passed through in sinking for chalk, which is worked here by means of a shaft and underground galleries. In a sand-pit between the kiln and Mozzels the following section was shown (1859):—

Basement-bed of the London Clay. Brown clayey sand, with green grains and flint-pebbles, about 2 feet.

Reading Beds. Sand, chiefly white, with layers of laminated iron-sandstone; the upper part very coarse, the lower finer. I was told that 25 feet of sand had been found.

The southern part of the outlier, from Mozzels to Moors End, was very hard to make out, the beds being much disturbed, and thrown, by faults apparently, into places where one would not at all expect to find them. Strangely too it would have been almost impossible to map this part at all rightly but for the clear *natural* sections that occur, a very unusual thing in inland Tertiary-districts. These sections however were not to be seen without some trouble.

The wood W.S.W. of the ruined church of Ackhamstead does not look, from any spot outside it, a very promising place for geological sections, and the thick underwood would be quite enough to satisfy many explorers as to the need of forcing their way through it. However the water that flows over the moist ground of the common on the north collects, inside the wood, into streams, which having a sharp fall, cut for themselves channels of some depth, often rather steep-sided and with miniature waterfalls. In one of these the London Clay and its basement-bed (with ironstone, septaria, and fossils) were cut into, showing that this formation occurs here at a comparatively low level, far lower than the Reading Beds at Lane End. The streams all flow into a large and deep swallow-hole at the eastern end of the wood. This is in the Chalk; but the Reading Beds come on at once: for I saw the green bottom-bed in a saw-pit close by, at the southern edge of the wood. At Moors End there is mottled plastic clay by the roadside. Now both that place and the saw-pit are in the bottom of the valley, whilst the rising ground to the S.E., that is in the direction of the general dip of the country (a direction therefore in which one would expect higher beds to come on) is bare Chalk, giving evidence of a fault, or other disturbance, running N.E. from Moors End and throwing down the Tertiary beds on the N.W.

At the most southern point of Moor Common, that is just above Moors End, I found traces of the basement-bed, and higher up, by the cross-roads, there were some small shallow pits in the London Clay itself. The hill to the west however is Chalk, capped by "clay-with-flints" at the higher parts. This state of things continues further northward, for on the eastern side of the road that, skirting Moor Common, runs N.N.W. along the bottom of the valley, there are frequent signs of the Tertiary beds, whilst on the other side the Chalk rises to a much greater height than that of the London Clay on the Common. This gives evidence of a second fault, or other disturbance, running N.N.W. from a point a little west of Moors End to the bend of the road west of Mozzels, and with a downthrow on the east.

There are swallow-holes at the western corner of the wood on the eastern side of the road at the above bend, and here again some of the streamlets that feed them lay bare the beds in the wood, and show along their channels sand (with pipe-clay and iron-sandstone) and mottled clay. Now not only is the hill to the S.W. chalk, but so also is that to the north, leading one to conclude

that there is a third fault, with a southerly downthrow, along the small valley N.W. of Mozzels.

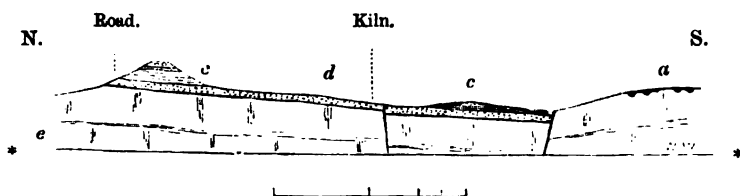
A stream runs along the line of the second and main fault at its northern end, and flows into the swallow-holes in the wood.

On the western side of this fault a small patch of the mottled clay and the bottom-bed spreads a short way up the flank of the hill, along the road to Perrin's Spring; showing that there is here not a fault only, but also a trough.

To return to the wood west of Ackhamstead: It is on the Tertiary beds, and the London Clay comes very near to its north-eastern edge, whilst the rising ground close by, towards Moor Farm and above Ackhamstead, is Chalk, leading one to infer the presence of a fourth fault, or other disturbance, running N.W. along the edge of the wood to Mozzels; an inference which is strengthened by the fact that the two S.W. and N.E. faults described above seem to end suddenly on the N.E. (as they also do on the S.W.), as if cut off by another fault at right angles, or nearly so, and with a downthrow on the S.W.

I was led to think that these four disturbances are faults, by the sudden manner in which the Tertiary beds are brought on by them, as well as by the fact that they all seem to end off suddenly at both ends, as if cut off by other faults. To suppose an area to be altogether surrounded and included by faults, and dropped down in mass, may be thought an almost unwarrantable thing by very many geologists, and these four faults would not have been marked on the Geological Survey Map had the difficulties of the case seemed surmountable in any other way. This outlier was worked at carefully for a long time, and some time after it had been mapped, SIR A. RAMSAY went to Lane End with me, and after a detailed examination of the ground and sections we were unable to suggest any other explanation. Fig. 29 illustrates the appearances above-described.

Figure 29. Section across the Lane End Outlier.



Horizontal Scale 2 inches to a mile. Vertical Scale twice as large.

- |                       |                           |
|-----------------------|---------------------------|
| (a) Clay-with-flints. | (d) Reading Beds.         |
| (b) Pebble-gravel.    | (e) Chalk.                |
| (c) London Clay.      | ** Approximate sea-level. |

From Mozzels northward to Bolter End the boundary-line is much hidden by wood.

At Oakington Kiln, near the northern end of the Lane End outlier, a patch of the Reading Beds, consisting of alternations of sand and clay, capped by brick-earth, has been found. At one part of the brickyard the Chalk was not touched at a depth of 25 feet; whilst close by, and at a slightly higher level, it is at the surface, so that this is most likely nothing but a pipe.

Just west of Grove Farm, near the eastern end of the Lane End outlier, there is a small hillock of sand, overgrown with wood; and at New Moor, further eastward, MR. H. B. WOODWARD notes (1869) that "there is a pipe



(large enough to be shown on the map) in which sand has been dug to a depth of seven feet."

By the road nearly a third of a mile S.E. at Wood End Farm, about three miles south of Lane End, I saw some mottled clay. This must fill a pipe, as it is in the midst of the chalk-country, and is not at a higher level than the chalk near by.

At Mount Pleasant, about two miles S.E. of High Wycombe, "the ground rises 30 to 40 feet higher (than the chalk near by) in consequence of an outlier of the sands and mottled clays."\* I could see no section of these however; but in a field (included in King's Wood on the map) at the south-eastern end of the outlier, there was (in 1859) a small pit showing the bottom-bed (consisting of about two feet of greenish and yellowish clay, with a little green sand, but no flints) resting unevenly on the Chalk.

S.E. of this there is a larger outlier, the northern boundary of which is hidden by the gravel of Flackwell Heath. Along the road up the hill, nearly half a mile east of Pigeon House Farm, mottled clay occurs a little way above the Chalk, as is also the case, at about the same level, on the roads that run down into the valley at Lower Moor and Woburn Green. Between these last roads the boundary is shown by a slight but well-marked rise of the ground. There is gravel on the southern spur of the outlier, towards Woburn Hill.

On Woburn Hill I saw some mottled clay below gravel in the remains of old chalk-wells. This is most likely a separate patch.

#### *North of the Thames between the Loudwater and the Misbourn.*

##### MAIN MASS.

On the northern side of the Thames near Windsor the gravel spreads farther from the river than on the southern side, and the line between the Chalk and the Reading Beds is therefore quite as doubtful as in the latter tract, but it seems to run north-westward to Burnham.

From the small valley west of Burnham the boundary-line runs N.W. to Hedsor, following the contour of the ground, and therefore winding up and down the hollows. From Hedsor it again takes its usual north-easterly course; but soon turns eastward, nearly to Fulmer, owing to the denudation that has formed the Hedgerley valley and separated the Beaconsfield outlier. The broadest space taken up by the Reading Beds in this district is between Burnham, Hedsor, Woburn Green, and Hedgerley; but over a great part of it they are covered by gravel.

From Fulmer the Reading Beds spread northward, capping the hills on the western side of the Misbourn valley to some point between the Chalfonts; and capped as far as Gerards Cross Common by London Clay, and everywhere by gravel, which latter makes the northern boundary very doubtful.

MR. POLWHELE noted that "at Horse Harness, north of Burnham, plastic clay may be seen in the ditch." At Burnham Grove a thin strip of this formation, less than half a mile long, crops out from beneath the gravel that covers the hill. Along the valley to the east and south denudation has laid bare the Chalk for some distance, and on great part of its eastern side a little of the Reading Beds shows between the gravel and the Chalk. In a pit on

\* PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xi. p. 82.

the southern side of the road, less than a mile east of Burnham Church, the following section was shown (1858):—

Brown flint-gravel, 10 feet or more.  
 Reading Beds { Mottled plastic clay, brown, blue and crimson } 5 or 6 feet.  
 { Green sand, rather clayey (bottom-bed) }  
 Rubbly chalk.

At the junction of the gravel and the clay much water oozed out, and wore away the latter. In another pit, less than a quarter of a mile to the north, there was only gravel above the Chalk.

MR. POLWHELE was told that "in digging a shaft for getting chalk, a mile east of Burnham, 30 feet of gravel, 20 of plastic clay, and two of greensand were passed through in descending order."

A short distance N.E. of Burnham Grove a junction of this formation with the Chalk was to be seen in 1859. The top of the Chalk was very regular and even, with a slight dip to the south. On it was greensand about two feet thick, with oyster-shells and a few small flints; and this again was overlain by red mottled clay.

From MR. T. R. POLWHELE's notes we learn that "on the road near Batten's Barn there is plastic clay in the ditch. At Foxes Den is a swallow-hole, half way down which the chalk may be seen; and in a hole near a cottage in Cavebrook Wood 30 feet of gravel and sand were seen on chalk."

About a third of a mile nearly south of Hedsor the road down the hill towards the Thames shows the following beds in descending order:—

Drift - - { Dark brown gravel.  
 Brown sand, with a little gravel.  
 Light brown clay.  
 Pink and pale blue mottled clay.  
 Reading Beds - { Very pale bluish clay, with lenticular layers of crimson-red sand.  
 Pinkish clay, somewhat sandy.  
 Brown sandy clay, with flints and pebbles.

Chalk-with-flints.

The section was anything but clear when seen in 1857, and I then knew next to nothing of the Tertiary formations of these parts. My colleague, MR. C. E. HAWKINS, who was engaged in 1869 in surveying the Drift of this neighbourhood, tells me that I have omitted to notice the green bottom-bed, which was plainly shown in several places, with green-coated flints.

The brickyard on the hill half a mile north of Hedsor gives a better section of the same formations; the general order of the beds, shown by the various parts of the pit in 1859, being as follows:—

	FEET.
Dark reddish-brown gravel; consisting of flints, pebbles of quartz-rock, and of quartz, and a few pieces of grey-wether-sandstone	over 12
Reading Beds { Varies coloured clay	probably from 15 to 20
{ Light-coloured sands, the upper part clayey	about 5
{ Bottom-bed; greenish clay and clayey sand, with flints at the base	2

MR. POLWHELE has noted that "on the road from Blake's Wood to Woburn Green there is a junction-section of the Reading Beds and the Chalk; but the plastic clay of the former has slipped down the hill in places."

At the pit, marked on the old Ordnance Map, about a quarter of a mile south of Holtspar Heath, Tertiary sand is got from below the thick cap of gravel, and down the road, further southward, the following are shown:—

Reading Beds { A little mottled plastic clay.  
 Bottom-bed. Clayey greensand with large flints at the bottom in parts, about a foot.  
 Chalk. The junction very irregular, owing to pipes.

I saw also (in 1866) a little light-coloured sand in one of the old pits at the brickyard by the high road a mile west of Beaconsfield, and I was told that at that town water was got at a depth of about 12 feet, the gravel being sometimes as much as 16 feet thick, and underlain by clay, below which latter there was said to be sand.

In the small wood just northward of Helmet, a mile and a half S.E. of Beaconsfield, there is a long deep hollow, from the track through the wood down to the southern edge. It ends abruptly either way, and I could not well make out whether it was artificial, or simply a swallow-hole. At its southern end, almost vertical, it shows what may be a junction of the Reading Beds and the Chalk, the section being :—

Brown loam (wash) 5 to 7 feet, or more, with from a few inches to a foot of grey clay with brown sand (bottom-bed ?) at its base; small flints at the junction with the chalk.

Rubbly (reconstructed ?) chalk-with-flints.

"In sinking for chalk about 200 yards south of Overs, 40 feet of gravel and 20 feet of clay were found before touching that rock, according to the workmen." (From MR. POLWHELE'S Notes.)

For some distance eastward there were no sections, as far as I know, when the Survey was first made, but MR. HAWKINS has supplied the following notes (1869):—

"East of Castleman plastic clay was found beneath 20 feet of gravel."

"Plastic clay has been found (under gravel ?) in a pit in Ash Coppice."

"The depth to the chalk on the crest of the hill between Abbey Park and Hickenham is said to be 80 or 90 feet; about 40 feet down a mass of pink clay, 10 to 12 feet thick, was found at one place."

"At the kiln about a third of a mile S.E. of Starveall the beds found were as follows, according to the workmen :—

	FEET.
Gravel	- 18
Reading Beds { Clay	- 12
{ Sand	- 50
Chalk.	

"In the road-cutting through Burnham Wood red mottled clay may be seen beneath the brickearth, sand and gravel; and in an old pit at the bottom of the hill, in the wood on the western side, there are layers of greensand."

PROF. PRESTWICH'S descriptions of the sections that were formerly to be seen are as follows :—

"From Starveall to Hedgerley is a succession of sections, which are interesting from their exhibiting the very rapid structural changes which take place in these sands and mottled clays." Between two sections, at Hedgerley and Penlands, "less than half a mile apart . . . the mottled clays almost entirely disappear and are replaced by sands."\*

The details of the Penlands section are as below :—†

	FEET.
Ochreous Gravel	- 2 to 3
Reading Beds, { Mottled clay	- 4
40 feet. { Light-coloured sands, with a few irregular seams	
{ of mottled clay	- 30
{ Light-bluish clay	- 4
{ Greensand, clay, and flints	- 2

In 1869 MR. C. E. HAWKINS noted a thickness of about 35 feet of the brickearth (Reading Beds), passing down into sand with layers of pink plastic clay.

\* *Quart. Journ. Geol. Soc.*, vol. x. pp. 90, 91.

† PRESTWICH, *Water-bearing Strata around London*, p. 26.

The Hedgerley section was at a brickyard on the slope of the hill, and on the western side of the road, and the beds shown were\* :—

London Clay	{	Brown and bluish clay with <i>Septaria</i> .
		Brownish clay.
Reading Beds, 40 feet.	{	Basement-bed. Blackish clayey sand and greensand, underlain by flat tabular, fossiliferous masses of greensand, with a calcareous cement, and containing a few flint-pebbles.
		Mottled clays : light greenish-grey and red, with a few layers of sand ; 30 feet.
		Fire-brick earth ; 5 feet.
		Greensand, clay, and flints ; 5 feet.

Chalk.

In 1869 MR. HAWKINS noted "from a foot to 5 feet of pebbly gravel, with layers of red sand, at the top."

"In sinking a well about 30 yards N.W. of the square pond by the high road across Gerards Cross Common, seven or eight feet of variously coloured mottled clays were seen, beneath six feet of brownish gravel ; and in another well, on the southern side of the church, there was light-blue clay beneath eight or nine feet of gravel."

Plastic clay occurs beneath the brick-earth and Gravel at Gold Hill, and MR. POLWHELE notes that "in a pit on the top of the hill, about three quarters of a mile south of Chalfont St. Peter, gravel was shown resting in a hollow of plastic clay, with sand beneath, of which last there was said to be from 30 to 40 feet."

"About ten chains north of the kiln at Oak End is a section of the junction with the Chalk, the beds being as follows" (from MR. HAWKINS' Notes, 1869) :—

									FEET.
Loamy gravel	-	-	-	-	-	-	-	-	5½
Reading Beds	{	Red mottled clay	-	-	-	-	-	-	4
		Dark blue or slate-coloured sand	-	-	-	-	-	-	¾
		Green sand	-	-	-	-	-	-	3
		Greensand, with green-coated flint-pebbles and a few unworn flints	-	-	-	-	-	about	¾
Chalk : surface slightly uneven	-	-	-	-	-	-	-	6	

At the kiln, the plastic clays of this formation were worked for tiles, &c. There was no good section when I was in that neighbourhood, PROF. PRESTWICH however remarks that "a somewhat similar section (to that at Hedgerley) is exhibited at Oak End,"† and MR. HAWKINS got the following account of the section from workmen in 1869 :—

Reading Beds	{	Mottled clays ; 9 feet.
		Sands of various colours ; 21 feet.
		Green sand ; 2 feet.

Hence south-eastwards to the Colne, I know of no section of the Reading Beds, which are hidden by the Valley Gravel south of Denham.

#### OUTLIERS.

In the neighbourhood of Penn (east of High Wycombe) are six outliers. At the highest part of Ash Hill there are signs of the occurrence of a small patch of plastic clay beneath the Gravel.

The village of Penn is on a fairly marked outlier, the north-western part of which is, however, hidden by brick-earth and gravel. At Town Farm the Chalk is at the surface, but a little way up the road (to the north) there is plastic clay, as also in the fields on the east, and along the roads just S. and S.E. of the church.

\* PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. vi. p. 268 ; and Water-bearing Strata around London, p. 25.

† Water-bearing Strata around London, p. 25.

Mr. H. B. WOODWARD noted, in 1869, that "the junction with the Chalk was well seen in the road-cutting north of Town Farm, the beds being"—

Pink and grey clay (with carbonaceous specks) -	-	-	} 2 feet.
Greenish clay with some black flint-pebbles and a few green-	-	-	
coated flints and large unworn flints	-	-	
Chalk.			

At Penn Bury, just to the east, there seems to be a very small thin outlier.

Less than half a mile further, in the same direction, another outlier comes on, and stretches eastward, with a doubtful boundary in Witherage Wood, to the cross roads, and thence southwards to Bailings. At the northern end mottled clay is shown along the road, whilst at the southern there is sand.

A little further east is a very small patch, the bottom-bed being shown just S.W. of Seagroves.

Between Aldiff and Forty Green, S.E. of Penn, there is a small sand-hill.

The hillocks of gravel S. and S.W. of the Penn outlier may perhaps hide traces of the Reading Beds.

*Coleshill, southward of Amersham.*

On the S. and S.W. of Amersham a large and well-marked outlier of this formation, together with the London Clay, forms the higher ground from Winchmoor Hill and Coleshill Green to the Pest House.

At the western end there is mottled clay; and hence, along their northern boundary, the Reading Beds rise sharply above the Chalk. On this side there were no sections west of Brickwick; but in the hollow just east of that place there is a swallow-hole; and along the road above the Pest House the bottom-bed is shown above the Chalk, with mottled clay higher up. The first is here rather more brown than green, and with the flints coated black, rather than green; altogether indeed very like the "clay-with-flints" over the chalk-tract. East and south of this the boundary-line is somewhat doubtful, but there is a swallow-hole at the farm west of Quarrendon.

At the north-western corner of Brentford Wood there was a brickyard, the pit supplying which (in the wood) gave the following section (1859):—

London	{	Bluish-grey clay; but little to be seen.
Clay.		Basement-bed; but little shown; a clayey sand, said to be 6 or 8 feet thick and to have a bed of pebbles near the middle.
Reading Beds.		Clay, throwing out water from the above.

I was told that in sinking a shaft in the brickyard, for the purpose of getting chalk, nothing but clay was found above that rock.

Along the road to the south there is mottled clay, and thence to Coleshill Green the boundary-line is well-marked by swallow-holes, of which there are many; one, indeed, in most of the re-entering angles of the outlier.

In an old pit at the south-western part of the Green mottled clay rests on the Chalk, the bottom-bed being absent.

The Reading Beds cannot be very thick here; perhaps not much more than 30 feet.

*Frog Hall, westward of Chalfont St. Giles.*

On the hill west of Chalfont St. Giles is an outlier slightly larger than the above, and like it rising well above the Chalk, and in great part capped by London Clay. It reaches from High Wood eastward to Hill Farm.

At the western end the Reading Beds are much hidden by gravel, but the northern boundary-line is shown by a swallow-hole nearly a third of a mile eastward of Stockings, and by another about the same distance further in the same direction.

At Frog Hall Kiln the section was as follows, in 1859:—

Gravel.

Basement-bed of the London Clay. Brown loam, with small flint-pebbles at the base, lying irregularly on the bed below.

Reading Beds.	{	Light-blue and yellow mottled plastic clay, throwing out water and passing into crimson-mottled plastic clay. Brown and buff clayey sands. Bottom-bed; not shown, but said to consist of about a foot of flints capped by coarse sand.
------------------	---	--

At the lower part of the pit there is brown, bedded brick-earth, lying conformably on the sand of the Reading Beds, the two looking like parts of one and the same formation.

On the east and south of the kiln there were no sections, but the boundary-line is fairly marked by the rise of the ground. Near Rowlings it is doubtful, although there is a swallow-hole there, and another nearly half a mile N.W., by the road between Hodge Wood and High Wood.

#### *Beaconsfield.*

This large mass has for the most part a doubtful boundary owing both to the absence of sections and to the presence of gravel. The Reading Beds however seem to spread over the high ground from Butler's Court to Stampwell, on the east; and to Great Bower Wood, Mount Pleasant, Hedgerley Green, and Bulstrode on the south and south-east, being not far separated from the main mass along a great part of the Hedgerley Valley.

MR. W. A. E. USSHER notes that "by the roadside near Butler's Court is the following section (1869)":—

Reading Beds.	{	Mottled grey, brown and yellow clay, passing down into bright ochreous and greenish-grey. Brown and greenish clay, with flint-pebbles and white and green-coated flints.
------------------	---	---

Chalk.

Speaking of this district PROF. PRESTWICH says, "On Stampwell and Pitland's Wood Hill the ground rises rather higher, in consequence of a thin outlier of the mottled clays and sands, round which the gravel sweeps, barely spreading over it in places,"\* and "In a section in Pitland's Wood thin patches of subangular flints occur apparently beneath the mottled clays."†

MR. HAWKINS noted, in 1869, that "a pit at the kiln gave the following section, and the depth to the chalk is about 40 feet."

Pink plastic clay, in places only; about a foot.

Light-coloured sand, with a thin layer of pipe-clay, about 8 feet.

In an abstract of a paper on pipes in the Chalk DR. BUCKLAND "refers to the epoch of the Plastic Clay (Reading Beds) the gravel and clay filling these cavities near Beaconsfield. Here remains of tortoises were found in the clay by the late Lord Grenville."‡ These fossils might perhaps come from the basement-bed of the London Clay, but some of the beds filling the pipes may be Drift, certainly the gravel is.

In a chalk-pit on the western side of the small N. and S. valley at Hedgerley, and just beyond the northern end of the village, a junction of this formation with the Chalk is shown. The bottom-bed consists of a foot and a half of light-green clayey sand, with flints at the base, and above it is light-coloured sand.

\* *Quart. Journ. Geol. Soc.*, vol. xi. p. 81.

† *Ibid.*, vol. x. p. 90.

‡ *Rep. Brit. Assoc.* for 1839, p. 76.

There is a patch of the Reading Beds at Taplow, covered by gravel except at its southern edge. Of this Mr. POLWHELE notes that, "in a lane on the north-east of the church (the new one, which is not in the place where the old one, marked on the map, used to be) there is a little plastic clay."

*Outliers between the Valleys of the Misbourn and of the Chess.\**

At Boddington Hill, about three-quarters of a mile east of Wendover, I noticed a pipe of sand and plastic clay.

By the road about a quarter of a mile S.W. of Choulesbury Church there is a sand-pit some feet in depth. The sand may perhaps be but a large pipe, as there is no proof of its spreading any distance; although, as some mottled clay was seen lying about at an old brickyard close to the road on the north-west, it is possible that this outlier may reach farther than is shown on the map.

The other outliers of this district are much farther to the south, the most northerly one between Cheneys Lodge and Burton's, about three miles nearly east of Amersham. It is very doubtful: indeed I saw no section; but merely judged, from the rise of the ground, that there was most likely a little of the Reading Beds beneath the gravel.

*Pollard's Wood.*

Northward of Chalfont St. Giles a mass of the Reading Beds (with a somewhat doubtful boundary, owing to a capping of Gravel and to the woods) forms the higher ground from the northern end of Pollard's Wood to The Vach.

In the northern part of the wood a pit, for the supply of the brickyard at Loudhams (on the north), showed the following section, in 1859 :—

		FEET.
Reading Beds.	Brownish clay.	
	Brown and grey sand, rather irregular	about $\frac{1}{2}$
	Mottled plastic clay, regularly bedded	6
	Grey clayey sand, the uppermost part irregularly hardened and at one part forming an 8-inch bed of sandstone†	about 3
	Pale green sand with a few small patches of crimson and brown, passing into the bed below	nearly 5
	Laminated clay of a like colour, with sand partings	about 1
	Clayey sand with green grains. A bed of black flint pebbles, some very small, near the middle, and lower down a bed of the same with many green-coated flints, some large. There are also a few very small quartz-pebbles,	about 2
	Chalk. A bed of large flints in the top at most parts. A few borings.	
	Junction even.	
	Bottom-bed, about 8 feet.	

Due east of Ivy House there is a swallow-hole at the edge of the wood; and by the road, on the south-east, mottled clay and the bottom-bed are shown.

*Newlands.*

Further toward the south-east a larger mass of the Reading Beds, almost wholly covered by Gravel, and therefore with a

\* The Valley of the Chess can hardly be said to reach north of Chesham, where it branches into many dry valleys.

† There is a specimen of this sandstone in the Museum of Economic Geology. See *Catalogue of Rock Specimens*, Ed. 3, p. 164. The locality is there wrongly given as "Peppard's Wood."

doubtful boundary, reaches, with an average breadth of about half a mile, from a little east of The Vach, where it nearly joins the foregoing outlier, to a point more than half a mile S.E. of Roberts.

There are no sections, but the boundary is for the most part marked by a slight rise of the ground. Mottled clay is turned up by the plough at the higher part of the field at the north-western edge of Shrubs Wood; and the same bed was most likely found at the old kiln just north of Roberts. There is a swallow-hole just south of Bowers; and about a quarter of a mile further south, along the road down the northern slope of the small valley, there is mottled clay; whilst on the other slope, just above the spot where the road from Ninnings joins this one, a trace of the green bottom-bed occurs.

*Chalfont Lodge.*

A wide-spreading mass of the Reading Beds, with a boundary for the most part made doubtful by a thick capping of gravel, is shown on the map as reaching from the hill-top above Chalfont St. Giles to the River Gravel near Denham.

The northern part is so doubtful that all I can say of it is, that the Reading Beds may end off at any point north of Ninnings, in sinking chalk-wells south of which place sand has been found below the gravel. The southern part is very broad, taking up the whole of the high ground between the Colne and the Misbourn.

MR. POLWHELE notes that "in a small wood just below Mopes a junction-section of the Reading Beds and the Chalk was shown. On one side of the pit there was mottled clay, with a thick bed of small green-coated flint-pebbles and white sand beneath: whilst on the other side there was scarcely a pebble, but bands of green sand and clay, with about 15 feet of sand above. North of Tile House another junction was seen, the order of the beds being mottled clay, green sand and flints (bottom-bed), and chalk. Mottled clay is also shown on the high road more than a mile north of Denham."\* The south-eastern end of this outlier is hidden by the Valley Gravel.

*Chorley Wood.*

This well-marked mass, the boundary of which is however hidden by gravel, spreads from Phillip's Hill, more than three miles westward of Rickmansworth, to Chorley Wood Kiln on the east.

There is an "old kiln" marked on the map, at the northern part of Phillip's Hill, but nothing could be seen of the beds that were worked there.

Just S.W. of King's Farm is a swallow-hole, and I think that there are others elsewhere, though they have not been noted.

At Chorley Wood Kiln the following section was to be seen in 1859. The names in brackets are those given to the different beds by the workmen:—

Reading Beds.	Plastic clay (paving clay).
	Clayey sand, brown and light-coloured, 1½ feet.
	Red-mottled plastic clay (tile-clay).
	Bluish-grey sandy clay (devil).
	Green sandy clay (fire-earth), with an irregular line of ironstone-nodules (red knob), below which it is more sandy, and passes into the next.
	Green sand.
	Bottom-bed. Flint-pebbles, some very large, in sand, greenish toward the top, brown and light-coloured lower down; about 12 feet.
Chalk.	



The pebbles from the bottom-bed here do not break so easily as those that are found in the basement-bed of the London Clay often do; and most of them break with the usual conchoidal fracture of flint, not in the splintery manner of the basement-bed pebbles.

*Outliers between the Valleys of the Chess and of the Bulbourne.*

*Cowcroft (or Tylers Hill).*

About a mile and a half east of Chesham is an outlier of the Reading Beds, with a small capping of London Clay at its northern part, where it forms a hill rising well above the surrounding chalk-country, whilst to the south it is thinner and less marked.

At Cowcroft Kiln there were two good sections. I was told that at the upper of these the clay of the Reading Beds was found beneath the London Clay (see p. 253). The lower one was as follows:—

	FEET.
Buff clayey sand - - - - -	about 3
Flint-pebbles in clay - - - - -	" 3
Yellowish clay - - - - -	over 2
White sand; about 3 feet from the top an irregular bed of sandstone, 6 or 8 inches thick, passing into the bed below:—	about 10
Reading Beds { Light-coloured sands with thin layers of clay -	" 4
Grey sands and laminated clay, more clayey towards the base - - - - -	" 8
Flints in dark clay with green sand; a few small rounded flints, some green-coated.	
I found a fish tooth in this bed.	
Chalk, with borings in the top part. Junction even.	

The first two beds may perhaps be drifted: if so, my section will be found to agree in the main with that noted by PROF. PRESTWICH in 1853.\*

In the wood just S.W. of Cowcroft there is a swallow-hole.

The eastern and southern boundaries are more doubtful.

At Sarratt a thin outlier, with a doubtful boundary, reaches from the church northwards to the Green. In the wood just north of the parsonage is a sand-pit, showing layers of black flint-pebbles in light-coloured sand, the first trace of the "pebble-beds" of the Reading Series that I met with in the country under notice (working from the west, and excluding the pebbly bottom-bed). Since this was written however (1864) a section of a more decided pebble-bed has been opened further west, see p. 183.

I was told that in making a well at a cottage at the highest part of Sarratt Green the following beds, most likely belonging to this formation (except the first), were passed through in descending order, and with a total thickness of about 35 feet (?):—Gravel, loamy clay, sand, and large flints in a greenish sandy matrix.

An outlier has been mapped on the east of Sarratt Church, the rise of the ground making it most likely that a trace of the Reading Beds exists there, beneath the gravel. No section of the former was seen however. For the same reason another outlier was mapped at Micklefield Hall, to the south-east.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 90.

## CHAPTER 13. LOWER LONDON TERTIARIES (READING BEDS).

### NORTHERN OUTCROP (*continued*).

#### *Main Mass, Middlesex and Hertfordshire.*

On the eastern side of the Colne the Reading Beds rise from beneath the alluvium of the river at a point nearly two miles north of Uxbridge, being followed a short way further north by the Chalk. The junction-line of the two formations winds northwards by Harefield for nearly four miles, and then returns to its normal north-easterly trend.

From the hills S.W. of Rickmansworth the winding boundary-line of the Reading Beds runs north-eastward, roughly parallel with the river Colne, to Hatfield Park, and along this tract of country this formation and the overlying London Clay together form a range of hills that rise well above the neighbouring Chalk.

In the lane about a quarter of a mile east of Highway Farm, south of Harefield, there is some mottled plastic clay; and at the junction of the roads a less distance to the north of the same place there is (1887) a small pit, from 12 to 15 feet deep, showing a little clay (drifted?) over coarse light-coloured sand, with a few small flint-pebbles and subangular flints, and near the middle a thin bed of reddish clay. This pit is wrongly marked "Gravel Pit," on the six-inch Ordnance Map. The sand is much like that in the large pit at Pinner (see p. 206).

In a large old pit about half a mile N.W. of the farm the pale greensand of the bottom-bed occurs above the Chalk.

Many years ago MR. TRENCH noted that "at the top of a large chalk-pit by the canal west of Harefield there is here and there a sandy bed, with black flint-pebbles, and a few subangular green-coated flints." This refers probably to a former state of the section next described.

At the Harefield Brick and Cement Works, west of the Almshouses, at the southern end of the village, a fine section, from the London Clay to the Chalk, was open in 1887, the succession being as in fig. 30, which was drawn by MR. J. G. GOODCHILD from my notes.

The junction of the Chalk and the Tertiary beds (seen along the southern part of the chalk-pit) is even, but cuts slightly across the dip of the former, from S. to N., to the extent of perhaps 2 feet, as far as seen.

Along the road down the hill from Woodcock Hill, by the edge of the park called Harefield Grove, and near the bottom of the small valley, the pale greensand of the bottom-bed was turned out of some holes dug for posts.

At the Woodcock Hill Kiln the upper pit gave the following section, in 1882, when it was clearer than at the time the district was surveyed:—

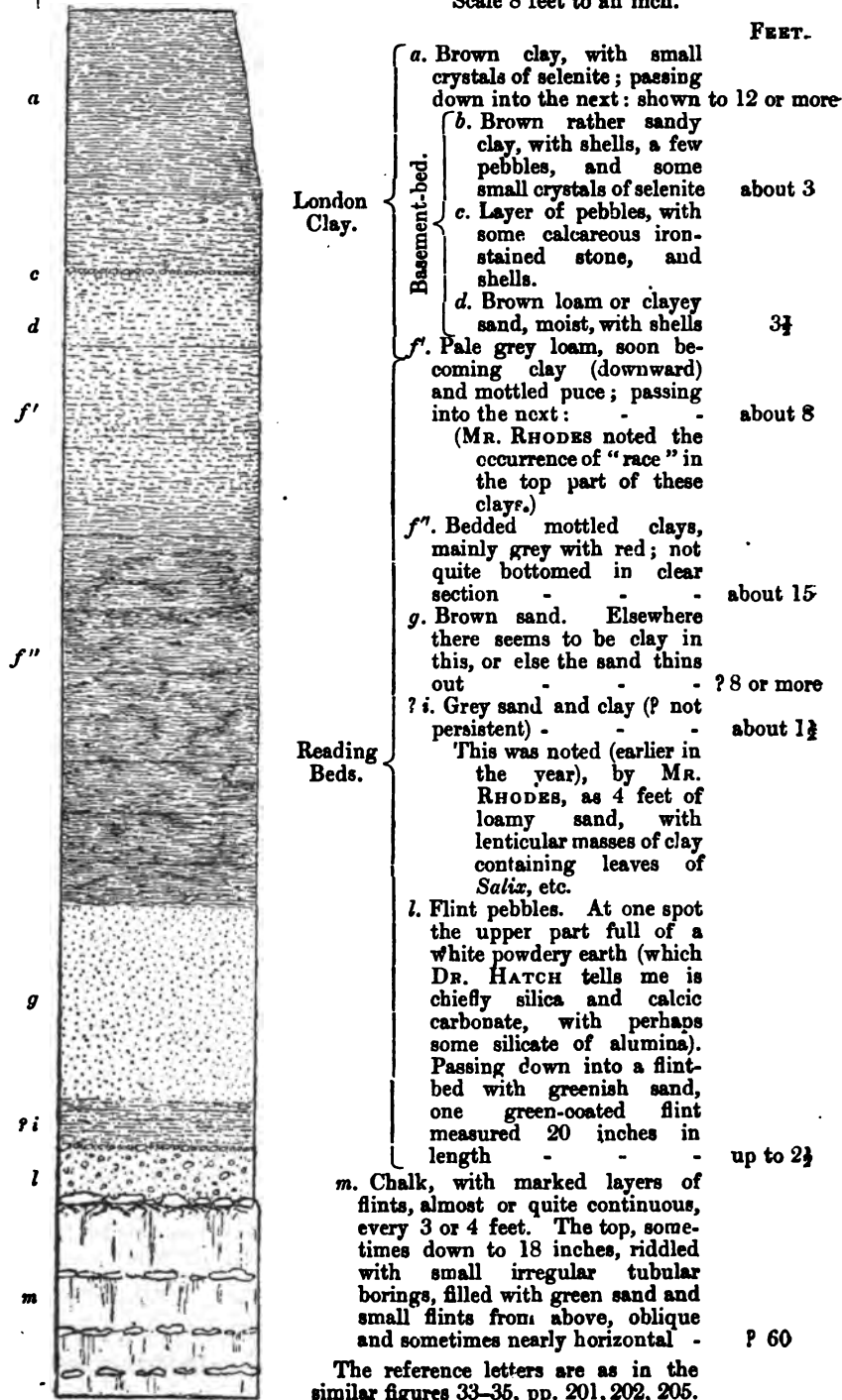
Clayey gravel, resting in hollows cut out in the bed below:—

Basement-bed	{	Brown and grey sandy clay, with a ferruginous bed (in which a cast of <i>Panopea</i> was found), $\frac{1}{2}$ 5 feet.
of the		Layer of flint-pebbles.
London Clay.		Brown loam, about 3 feet.
Reading Beds.		Mottled plastic clays, thick.

The lower pit showed about 10 feet of brown sand, with clay above and some apparently in it.

Figure 30. General Section at the Harefield Brick and Cement Works.

Scale 8 feet to an inch.



In draining the fields on the western slope of the valley a little southward of Piper's Farm mottled clay was found, whilst further S.E. there were three small pits, two in sand, and the other in a pebble-bed.

In the fields south and east of Aston's Lodge, just beyond Moor Park, mottled clay and sand were found in draining; the London Clay and its basement-bed coming on above, towards the Grove Farm. In the lane about a quarter of a mile west of the last place there is sand. Southward the Reading Beds have been laid bare for a long way back into the London Clay country, the broad outcrop of Ruislip Wood joining on to that along the escarpment by a narrow neck, so narrow indeed that the outcrop to the south of it was at first mapped as an inlier, and described as such.\* A later examination by Mr. BRISTOW showed however that the London Clay was barely denuded from the shallow gap.

The tract in question is on the N.E. and E. of Ruislip Wood, and takes up an area of about half a square mile, forming in great part a rough common-land quite different in character from the surrounding clay hills; and it seems to be bounded on the south by the large reservoir; but at this end it may perhaps reach a little farther east than is shown on the map.

In a ditch at the northern end of the new churchyard, a little below the toll-bar, I saw (in 1862) mottled clay, at the surface nearly up to the level of the church, but higher up capped by the brown loam of the basement-bed of the London Clay, giving a good starting-point for drawing the line between the two formations. In the high road just below the church there was also some red-mottled plastic clay.

West of the lane leading from the high road to Ruislip Wood there was a good section of the basement-bed of the London Clay some few feet below the surface of the ground (see p. 254), showing that the Reading Beds are at no great depth. Along the lane there are also signs of the basement-bed down the gentle slope towards the south, at the foot of which the Reading Beds are at the surface, the London Clay again coming on over them as the ground rises further to the south.

On the common between this lane and the high road there are many sections of the Reading Beds, indeed the shape of the surface of the ground has been quite changed by the pits, many of which have been sunk through to the Chalk. From those along the northern edge of the wood variously coloured mottled clay has been got, as well as light-coloured sand, whilst those in other parts do not seem to have yielded clay: perhaps the latter do not show the higher beds of this formation. From two pits, close together, I got the following section, remarkable for the occurrence of greensand some way above the bottom-bed:—

Reading Beds	{	Clayey greensand.
		Light-coloured sand, with a flint-pebble here and there.
		Bottom-bed; green clayey sand with flint pebbles.

Chalk.

Another pit showed light-coloured, false-bedded sand above a regular pebble-bed, the latter being also found at other parts; and a little S.W. of the spot where the "Green Lane" turns off from the high road, there were lying about some very large green-coated unworn flints, clearly from the bottom-bed.

Further south, between the wood and the high road, there is much sand, with plastic clay above on the west, but partly hidden by a drifted loam (brick-earth). On the other side of the high road, just south of the "Green Lane," are some old sand-pits; whilst a little to the east the London Clay seems to set in. About half way between this and the 15th milestone I again saw, in the ditch on the western side of the road, some greensand (but a few inches thick) above light-coloured sand, and Mr. TRENCH noticed, in the same ditch, "a greywether in the sand, perhaps in place, these stones being sometimes met with in the Reading Beds by well-sinkers."

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\* Memoir on Sheet 7 of the *Geological Survey Map*, p. 28. (1864.)

A little further towards Pinner there is sand on the north-eastern side of the road, and beyond the 15th milestone mottled clay.

On the common to the south shafts have been sunk through the London Clay to the Reading Beds, in order to get the white sand of the latter; mottled clay is found as well, most likely above the sand. The white sand is also got by open pits on a lower part of the common, to the west, where however it is in part covered by a drifted loam.

It seems that in this small tract there is mostly a bed of mottled clay at the highest part of the formation, whilst the lower and larger part is sandy. MR. TRENCH noted that "the Reading Beds are here about 30 feet thick (p more), and the sections seem to show that the various members are in lenticular masses. At one place the chalk just below the bottom-bed was much bored."

In those pits, at the northern part of the common, which reached to the Chalk, there was water, in February 1862, up to within a few feet of the top of that rock.

On the road south of Hamper Mill there is a long deep cutting, which shows a good deal of sand and a little mottled clay; whilst in the corner of a small wood, about a quarter of a mile further east, there is a small section of a bed of black flint-pebbles in sand, and again, "just north of Oxhey Lodge the pebble-bed occurs," according to MR. TRENCH's notes. A little S.E. of the last place there are some old chalk-pits, in which the Chalk is capped by gravel and sand, the latter belonging in part to the Reading Beds.

The long railway-cutting south of Bushey Station passes through all the beds from the top of the Chalk to the lower part of the London Clay, the level of the ground rising southward for some distance, and the slight dip being in the same direction. The section is now in great part overgrown, but according to the measurements of PROF. PRESTWICH† the Reading Beds are here more than 60 feet thick; I should think however that this is a little in excess. The junction with the Chalk may be well seen still, on the eastern side of the cutting, and also the whole of the bottom-bed, which, as PROF. PRESTWICH says, is "a remarkable development of the rolled pebble-bed immediately overlying the Chalk." The following section is made up from his account, together with my own notes. I should think that the thickness of the mottled clays has been over-estimated.

London Clay and its basement-bed; the latter 5 feet thick, with many fossils (see p. 264) and with flint pebbles.

	FEET.
Sands - - - - -	3?
Reading Beds, { Various-coloured mottled plastic clays, with a few beds of sand - - - - -	35 p
63 feet. { White and light-coloured sand, with flint-pebbles in parts - - - - -	10
{ Bottom-bed. Light green-grey sand, sometimes ochreous, with large green-coated flints at the base, and black flint-pebbles throughout - - - - -	15
Chalk-with-flints.	

During the widening of the line, in 1872 and 1873, I was fortunate in seeing some parts of this cutting reopened, and as they showed some slight changes and irregularities in the beds my notes are reproduced.

At the northern end of the cutting, at the western side, an irregular junction with the Chalk was shown at the back of the new buildings; and on the eastern side the section was:—

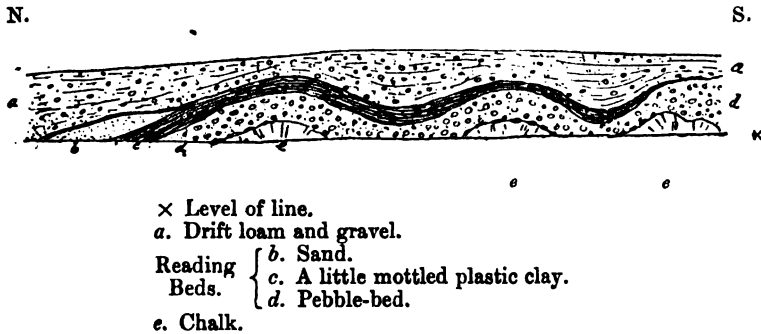
Drift of loam and gravel.  
 Reading { Light-coloured sand.  
 Beds. { Pebble-bed, with flints at bottom.  
 Chalk, touched just below the level of the line.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 91.

† *Quart. Journ. Geol. Soc.*, vol. vi. p. 270.

The junction was irregular, and just south the Chalk rises up in several sharp humps, as in fig. 31, which represents about 50 yards of the cutting :—

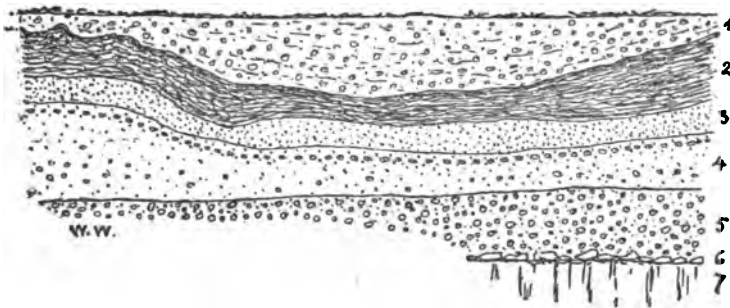
Figure 31. Section in Part of the Northern End of the Cutting on the London and North Western Railway, south of Bushey Station.



Just south the pebble-bed thickens, and then the Chalk rises up, for about 60 yards, partly to a height of 10 feet above the line, and there are only pockets of Drift. Then there is a mass of mottled plastic clay below Drift, and separated from the pebbles by a thin layer of sand. Still further, about 100 yards from the new Engine House, there is chiefly sand, with an irregular capping of gravel.

A small part of the eastern side of the cutting was cleared from top to bottom, at the site of the new boiler-house, about 250 yards north of the northern bridge over the line, and gave the section sketched in fig. 32.

Figure 32. Section at the new Boiler-house on the London and North Western Railway south of Bushey Station. 1872.



1. Loamy gravel, chiefly of flint-pebbles.
2. Green, yellow and red mottled clay, brownish at top on the south.
3. Whitish and red-stained sand, not sharply divided from the bed below.
4. Pale greenish sand; with a layer of flint-pebbles (many rather large) close to the top, another near the bottom, and other scattered flint-pebbles, especially at the north.
5. Bed of flint-pebbles, with a few flints (some of which seem to be green-coated, and may have been derived from the layer below).
6. Layer of flints, just below the level of the rails.
7. Chalk.

Along the next cutting to the south the Reading Beds are cut into as far as Oxhey Lane, sand and plastic clay being shown at the bottom, and the London Clay above.

The section at the brickyard at Chalk Hill, and on the southern side of the high road not far from the railway, was as follows, in 1862 :—

A little brown loam (at the highest part of the pit), perhaps belonging to the basement-bed of the London Clay.

Reading Beds	{	Plastic clay, light bluish-grey and greenish-grey, mottled with red, 15 to 20 feet.
		Light-coloured sand, not 2 feet shown.
		Pebbles (bottom-bed ?) have been got below.

At Bushey Kiln, at the western end of the village, and but little east of the above, there was a good section. The ends only, and not the middle part, of the pit were being worked when I was there in 1862, and the beds varied slightly ; but their general order is shown by Fig. 33. In 1886 the section was less clear.

At Watford Heath Kiln, on the south, there is another good section, the accompanying account of which (Fig. 34) is taken chiefly from MR. TRENCH's notes, but with a few additions from my own.

From Bushey there are none but small sections for some distance. South of Aldenham sand is shown in the lane just N.E. of Burnt Farm ; just S.E. of Patchets Green there is mottled clay, above which the loamy basement-bed of the London Clay comes on, and in an old chalk-pit in the hollow to the east there is sand at the top.

Some swallow-holes in this neighbourhood have been noticed by the Rev. J. C. CLUTTERBUCK.\*

In another chalk-pit, between Letchmoor Heath and Round Bush, there is, above the Chalk, sand with pebbles and, here and there, large unworn flints at the base, which may belong to the Reading Beds. There must be a steady southerly dip here.

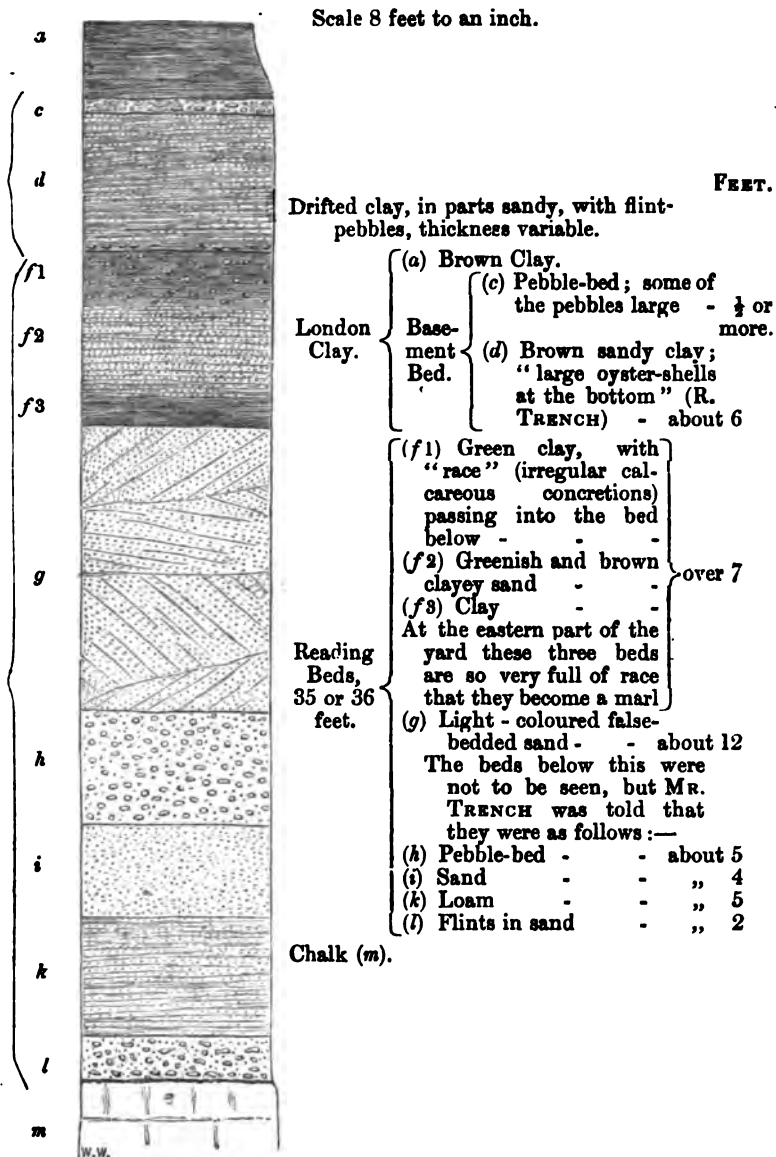
N.N.E. from Letchmoor Heath a spur of the Reading Beds runs out by Batler's Green to Newland, the beds above the Chalk having been denuded away, along the line of the high road, nearly as far south as Kendall Hall, and westward to Letchmoor Heath. Along the road from this last place to Batler's Green, sand is first to be seen, then chalk, and then sand again and in greater quantity. At the Green there is mottled clay, and though beyond this the Reading Beds are thickly covered with gravel, the presence of clay is clearly shown by the water thrown out from the latter. Sections were not wanting however and one of them was most interesting : it was in a gravel-pit on the hill-top, about half way between Radlets and Batlers' Green : the bottom of the pit seemed to be formed of a hard "pudding-stone" (a conglomerate of flint-pebbles in a sandstone-matrix) which was exposed in many parts, and everywhere at the same level ; so that it is most likely in place. It belongs to the Reading Beds, and where best seen was evenly jointed, the joints passing right through the pebbles, as is the case in many of the loose blocks lying on the surface and in the brick-earth in Herts, &c. There have been other pits near by.

Along the roads south and east of Newland both sand and mottled clay are shown ; west of Radlets there are swallow-holes ; and in two old chalk-pits, a little west of south of the same place, there is sand at top, as also at the highest part of another, about half a mile east of Batler's Green.

MR. TRENCH noted that "at New Organ Hall, in an old pit above the gamekeeper's lodge, conglomerate was found." More lately another pit was opened, about a quarter of a mile east of the lodge ; and this I saw in 1870, when on a tour of inspection with Sir A. Ramsay. The pudding-stone, like that just described, is made up of flint-pebbles in a hard siliceous base, and without doubt belongs to the Reading Beds. The pit is some way down the flank of the hill (facing westward), and the stone is in massive and tolerably regular layers, broken up by joints, and clearly in place : MR. H. B. WOODWARD noted, in 1869, that "the pebbles vary in size from that of a pea to that of an egg, and on the surface they are disintegrated from the rock and form a gravelly soil, which is mixed up with clay washed down the hill-side." Part of the park was drained in 1862, and during the progress of the work I saw London Clay, and its brown loamy basement-bed, a little south of the house, whilst lower down mottled clay and sand were cut into.

\* *Trans. Watford Nat. Hist. Soc.*, vol. i., pt. 5, pp. 127, 128 (1876).

Figure 33. General Section at Bushey Kiln.

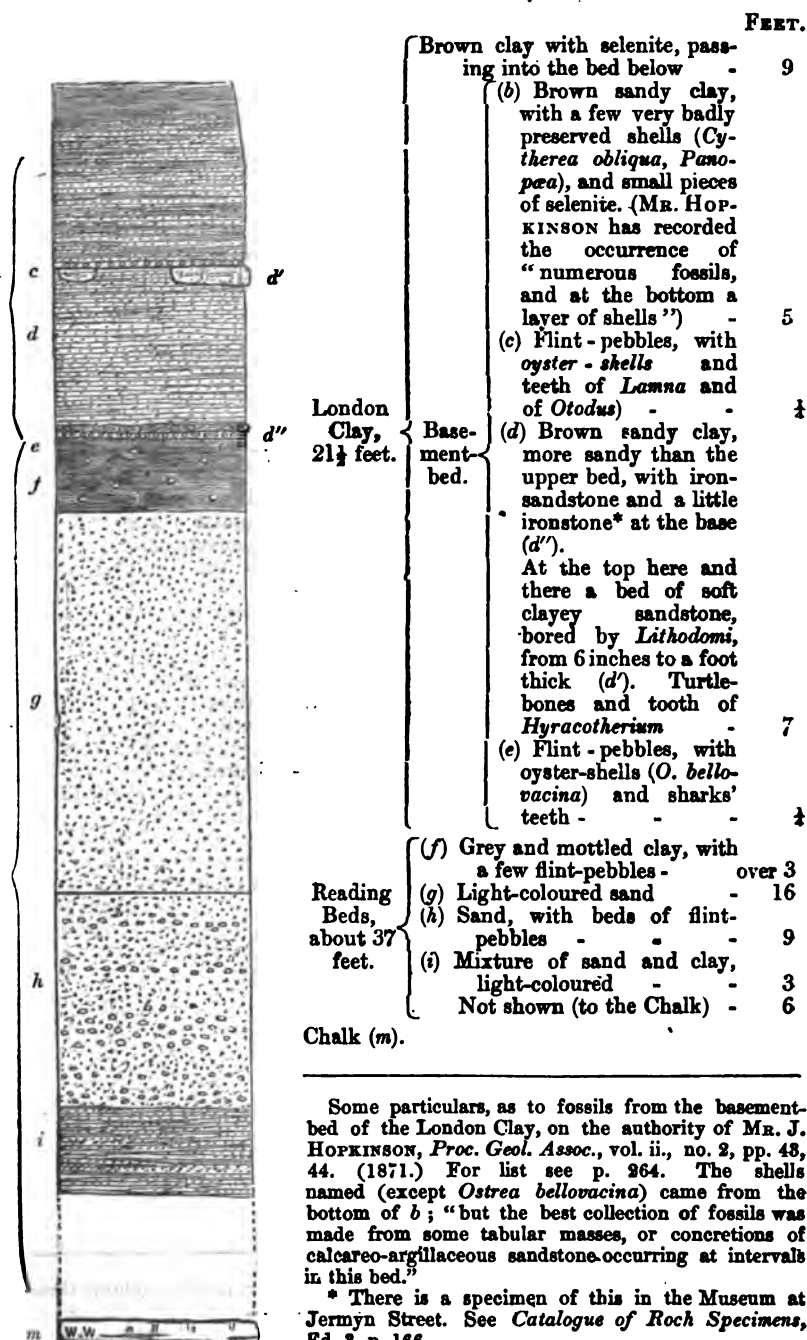


I have tried to mark corresponding beds by the same letters in this and in the three sections, Figs. 30, 34, 35, but I cannot do so with certainty.



Figure 34. General Section at Watford Heath Kiln.

Scale 8 feet to an inch.



The Reading Beds thence reach northward to Hound's Wood, the Chalk however cropping out some way up the valley west of Shenley, and then again take to their north-easterly trend, by Shenley Bury to Mims Park, their outcrop forming, between the last two places, but a narrow band between the London Clay range and the Chalk-district.

A little above the church at Shenley Bury there is chalk along the road, but higher up, to the south, sand. Just outside the northern edge of Combe Wood, west of this road, I saw (in April 1862, after very wet weather) some small swallow-holes in full action; and a little to the N.E. there is a chalk-pit showing sand at the top, so that the line of junction with the Chalk is fairly marked here.

Near North Mims the Tertiary beds have been much cut back by denuding actions southward, so that the Chalk is bare of them in the lower part of the valley thus formed, to half a mile beyond Mims Hall and thence westward to Pink Farm and Rabley. Mr. TRENCH supplied the following notes: "The brook that flows along this valley, from Rabley to North Mims, has no outlet, but the water is lost in swallow-holes, which thus receive the drainage of some 20 square miles of country."

"In the chalk-dell N.W. of Warren Farm (Warren Gate?) there is a poor junction of the Reading Beds and the Chalk, the bottom-bed (about 18 inches of brown sand, with black flint-pebbles and green-coated flints) filling pipes in the latter." A little higher, in the same direction, light-coloured sand is shown in a pond.

The cutting along the lane from South Mims to the lodge at the southern point of Mims Wood, gave the following section (in 1862) at a spot near the bend shown on the map.

Clayey soil.

Reading Beds.

Brown, rather clayey sand.  
Fine, bedded, white sand; at one part alternations of sand and clay for about a foot from the base; at another, thin layers of clay throughout the sand.  
Sand, with flint-pebbles and flints.

Chalk.

Sand with pebbles may also be seen overlying the Chalk on the southern side of the high road close to the county-boundary, as marked on the map; and, according to Mr. TRENCH's Notes, "about half a mile to the N.W., where the other road up Ridge Hill branches off, there is sand."

In a small sand-pit, on the western side of the road a little N.E. of Pink Farm, the beds shown (in 1862) were as follows:—Mottled clay, from about five feet thick to next to nothing, over light-coloured and white sand, mottled with red to about a foot from the top, about nine feet shown. There are some lumps of iron-sandstone lying about, and according to a note of Mr. TRENCH's, which I suppose refers to this section, there are small pebbles in the sand, and beneath it is brown clay.

East of the above, but on the western side of the next road, a little sand is shown above the Chalk in an old pit, and S.E. of this there is a large chalk-pit, at the western end of which the Chalk is capped by from three to five feet of sand, &c., there being at the junction a little clayey greensand and small subangular flints and flint-pebbles (at some parts green-coated, at others not) and here and there some red ironstone.

Close by, and westward, is a large old pit, the sides of which are much nidden and overgrown, so that the section is not clear. At the southern end there is at the top grey plastic clay, with much "race" here and there; then brown and light-coloured sand, and lower down chalk. At the other (northern) side there is nothing but sand over the Chalk, and the top of the latter is as high as, or higher than, the mottled clay and London Clay in the brickyards near by, to the south and west, showing a south-westerly dip. The junction of the sand and the chalk was only shown at one place, where in the lowermost 15 inches or so of the former there were black flint-pebbles and unworn flints (some very large), but no green grains, nor any green-coating on the flints.

South of Pink Farm are two brickyards, one on either side of the lane; that to the east is the newer, and is known as Rabley brickyard, the other as Pink Farm brickyard. At the former the pit was in the eastern part of the field, and it showed (in 1862) from six to eight feet of plastic clay, bluish- and greenish-grey, brown and yellow, mottled with red; at the latter the Reading Beds were not touched (see p. 255).

MR. TRENCH noted that "from South Mims to Hatfield Park there are no good sections, and the many swallow-holes give only an approximate boundary-line, owing to the amount of sand in the Reading Beds. S.E. of Mims Street this formation gives rise to a sandy soil in the fields."

On the road, about 10 or 11 chains east of Warren Gate, and in an old chalk-pit on its southern side, there is light-coloured sand with flint-pebbles, above the Chalk.

From Welham Green and Marsh Moor an irregular-shaped spur, which spreads over Dulsham Green and Chantry Green, may perhaps be separated from the main mass along the channel of the brook east of the first two places; in which case it would of course be an outlier. The north-western boundary is rather doubtful, owing to a covering of gravel. In the lane N.E. of Downs Farm there is a little light-coloured sand.

From Marsh Moor the boundary-line runs northward, parallel to and east of the high road, to Hatfield. Within the grounds of the house, about a quarter of a mile south of Hatfield Church, there was a small pit in light-coloured sand, which however will most likely be soon filled up (1863).

From Hatfield the boundary-line runs eastward towards Hertford, along the right bank of the valley of the Lea, crossing the borders of Sheets 7 and 46, and therefore partly just out of our district, and it is followed by that of the London Clay. Many N. and S. valleys have, however, been worn back southward far enough to show the Reading Beds, and sometimes the Chalk also, along their lower part. At the last, near Bayford, the outcrop is much hidden by Boulder Clay, which spreads up the slope.

Beyond this, in Sheet 47, the Drift almost wholly hides the outcrop, which still follows the valley of the Lea, to Amwell, whence it turns southward and re-enters our district at Hoddesdon for about a mile, and is then much hidden by River Gravel. The sections in this tract have been described in the Memoir on Sheet 47.

At Hatfield Park Kiln, at the eastern edge of the park, the pits give a very good section from the Drift down to the Chalk. On the eastern side of the road, the higher pit shows the former over London Clay, and the lower one shows London Clay and its basement-bed over the Reading Beds; whilst on the other side the higher pit also shows London Clay with a little gravel, and the lower one all the beds from the basement-bed to the Chalk. The general section that one is thus enabled to make is as shown in Fig. 35.

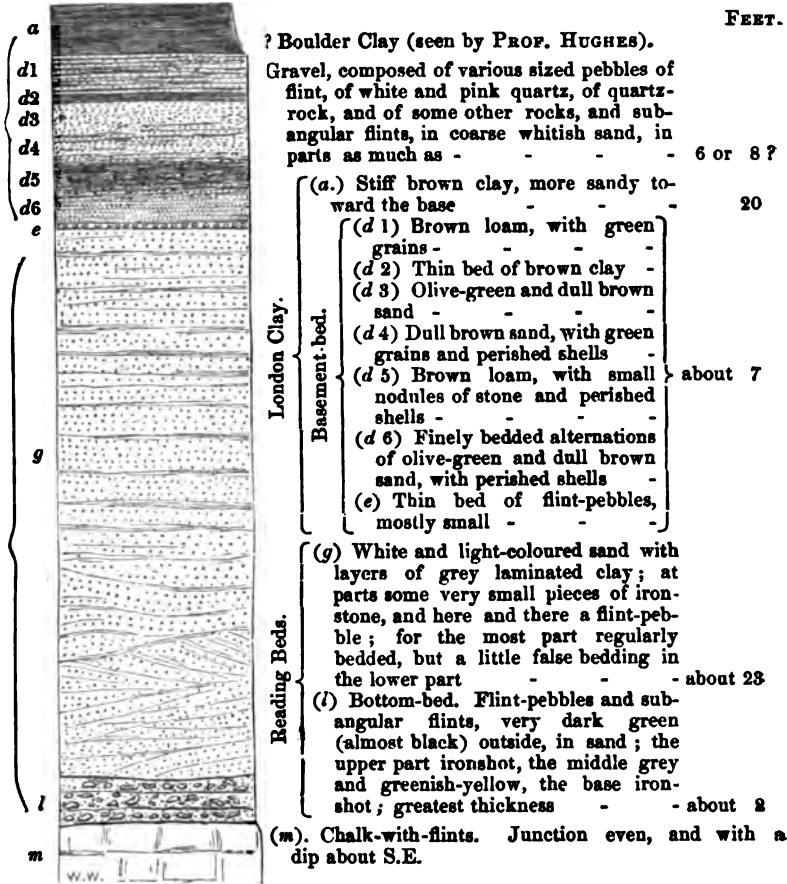
For some way east of Hatfield Kiln sections of any sort are rare, but MR. TRENCH noted that "in a wood by the brook, less than half a mile west of Bayford Church, and close to the margin of the map, there is a good section of laminated clay."

### *Inliers, Hertfordshire.*

Of the following inliers of the Reading Beds none are three miles off the outcrop of the main mass, and all are owing, in the first place, to a slight rise of the beds, bringing up the lower beds to a higher level than they would have reached if undisturbed, so that they have been laid bare by denudation.

Figure 35. General Section of the Tertiary Beds at Hatfield Park Kiln.

(Scale 8 feet to an inch.)



The top two beds (Drift) are not shown in the figure.

Reference-letters the same as in Figs. 30, 33, 34.

PROF. PRESTWICH makes the Reading Beds here to be about 27 feet thick,\* whilst in MR. TRENCH's note-book the thickness is given as 22 feet: the above is a mean between these. The entire absence of the mottled plastic clays is remarkable. MR. TRENCH gives the "basement-bed" a thickness of little more than three and PROF. PRESTWICH of about five feet. I should think that the section of this bed must have been clearer when I saw it (in 1863) than before, as neither of those observers seem to have noted its divisions, excepting the pebbles at the base.

\* *Quart. Journ. Geol. Soc.*, vol. vi. p. 270.

*Pinner.*

Pinner is on an inlier of an irregular shape, that follows the course of the brook from Wood Hall southward to Pinner Grove (the more southerly of the two places to which this name is given on the old map), and thence westward to Eastcot, from which place northward a strip of the Reading Beds is at the surface along the course of the brook that flows from the south of Pinner Green, and almost joins on to the outcrop at the latter place.

South-westward from Eastcot the narrow outcrop continues along the bottom of the valley, but is partly hidden by alluvium, by Ruislip to the west of Ickenham, with a spur up the valley to the north, between those two places, which almost joins the main outcrop by the reservoir.

The western end of this inlier, as originally coloured on the Geological Survey map, was thought doubtful, (See *Memoirs*, vol. iv. pp. 232, 233); but MR. BRISTOW was afterwards enabled to extend it, as above described, on the six-inch map.

At the lime-kiln about a quarter of a mile N.E. of Pinner Green chalk is got by means of a shaft, at the highest part of the field, sunk through about 40 feet of the Reading Beds. I was told that about seven feet of "green earth" with flints came next above the chalk, and that higher up a hard block or bed (perhaps greywether-sandstone) was passed through. The London Clay must come on just to the north. Close to the shaft, and at a rather lower level, was a sand-pit, showing many feet of light-coloured sand, bedded and false-bedded, with a thin layer of reddish clay near the middle; the whole much like the beds near Highway Farm, north of Uxbridge (p. 195).

PROF. PRESTWICH gives the following section of a shaft at Pinner\* :—

		FEET.
London Clay	Marly clay -	12
	Basement-bed {	Sand with shells and <i>Septaria</i> - 1
		Pebble-bed - 1
	Soapy marl -	5
Reading Beds, 39 feet.	Mottled clay of various colours -	26
	White and ferruginous sand with masses of sand- stone, very irregular -	4
		Green marly sand with [green-coated] flints - 4
	To the Chalk -	53

In clearing out the shallow ditch by the roadside just at the western end of Pinner Green, red-mottled plastic clay was found; and also in the ditch along the lane a little south of the turnpike. From West End to Eastcot the like occurs in many places on the northern side of the brook, just below the boundary-line of the London Clay.

MR. J. RHODES, who examined the Metropolitan Extension Railway from Pinner to Rickmansworth in 1887, found the long shallow cutting westward of the Pinner Station overgrown, but was told, by the engineer, that the western end was in yellow clay (the top part with race) and bluish clay at the base; whilst the central part was in mottled plastic clay, and the eastern end in greenish clay with green sand and pebbles.

In the lane that runs by the eastern edge of the wood marked "Ruislip Park," some clay, much like plastic clay, was seen in the ditch about 10 chains above the brook.

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 95, and vol. vi. p. 269. These two sections, however, do not agree in detail, and may be at different places. In the earlier account a layer of "large tabular septaria" is placed at the top of the basement-bed of the London Clay, and green-coated flints are noticed on the top of the Chalk.

Red-mottled plastic clay may be seen at the three roads less than half a mile south of the church; and also N.E. of the church, where the lane crosses the brook, up the course of which the Reading Beds are laid bare for a short distance.

It seems that here, as near Ruislip Wood (p. 198) there is a bed of mottled clay next below the London Clay; and the many places where the former throws out water from the loamy and permeable basement-bed of the latter served as guides in drawing the line between the two formations.

MR. TRENCH noted that at Pinner Hill Farm the Chalk was reached at a depth of 97 feet, through the London Clay and the Reading Beds; resting on it there was greensand."

He also mapped a very small inlier, along the course of a small brook, from the railway about a quarter of a mile N.W., to the road about the same distance on the west of Pinner Station.

#### Northaw.

For about a mile and three quarters along the brook-valley, N.E. and E. of the village of Northaw, there is an inlier of the Reading Beds and of the Chalk, the latter formation being at the surface, in the bottom of the valley, for three quarters of a mile.

I saw this inlier in 1862. The sections had then for the most part fallen in, and were much hidden by vegetation; but nevertheless they were well worth a visit.

On the more northerly side of the brook and eastward of the old brick-kilns are many old pits, the most westerly of which showed buff sand with black flint-pebbles, at the base more clayey and with almost unworn flints, over chalk. At another pit, very little to the east, there were a few small pieces of soft sandstone containing very small flint-pebbles; and at another the pebbles just above the Chalk were here and there cemented together by iron, and there were some small flat pieces of iron-sandstone and of ironstone.

The most easterly pit gave a small but good section, showing an even junction with the Chalk, as follows:—

	FEET.
Light-coloured sand (reaching farther up) - about	8
Grey clay, laminated by layers of sand and of ironstone; flint-pebbles come on at the base, or rather this bed passes into that below - - -	1½
Pebble-bed, with layers of sandy clay; the lower part more sandy and passing into the underlying sand -	2½
Dull brown and grey coarse sand, with flint-pebbles irregularly scattered throughout (but chiefly in the upper part) and with <i>oyster-shells</i> - - -	5
Flints, mostly black or very dark green outside, in sand - - -	½
Hard bed with small flints and <i>allophane</i> (P)* fitting closely on to the chalk, half an inch.	
Chalk-with-flints, jointed.	

PROF. PRESTWICH long since noticed here the occurrence of a "fine bed of the *Ostrea Bellovacina*," and also of "*Hydrate of Alumina*—[? *allophane*, a hydrosilicate of alumina] . . with the pebbles and flints in immediate contact with the chalk."† An account of this mineral and of its occurrence at the junction of Tertiary beds and Chalk has been given by PROF. MORRIS (see p. 106.)

The southern end of the inlier is rather doubtful, as there were no sections in that direction.

\* There is a specimen of this bed in the Museum at Jermyn Street.

† *Quart. Journ. Geol. Soc.*, vol. x. pp. 92 and 123.

Another inlier, N.E. of the above, reaches as a narrow strip along the bottom of the next valley, from the north of Northaw Wood to the road west of Gough's Oak, with a spur running some way northward, up the side-valley between Tallymore and Prestons. MR. TRENCH noted that the sand of the Reading Beds is shown, close by the brook, south of Newpark Farm and south-west of Chalk Farm", and MR. H. B. WOODWARD took the following notes, in 1871.

"A pit in the bottom of the valley S.S.W. of Newpark Farm gives the following section:—

Gravelly soil: black flints and quartz; 1 to 2 feet.  
Clay, with black pebbles; a foot.  
Greyish sand, with seams of pipe-clay; over 6 feet.

By the road at the N.E. corner of Northaw Wood, there is again sand, and "near the junction of the brooks south of 'Chalk Farm' is a pit showing:—

Loam, with black flint-pebbles (? basement-bed of the London Clay):  
6 or 8 feet.  
[Reading Beds]. Brown sand; over 4 feet.

"The Chalk does not come to the surface in this inlier, but it has been worked by sinking through the Reading Beds."

### *Outliers, East of the Valley of the Gade.*

At Wood Lane End Kiln, more than a mile east of Hemel Hempstead, it would seem that masses of the mottled clay of the Reading Beds are included in the brick-earth, or that there are pipes of the former; for tiles and drain-pipes are made there, as well as bricks, and the sandy brick-earth would be of no use for making them.

### *Bennets End, Hemel Hempstead.*

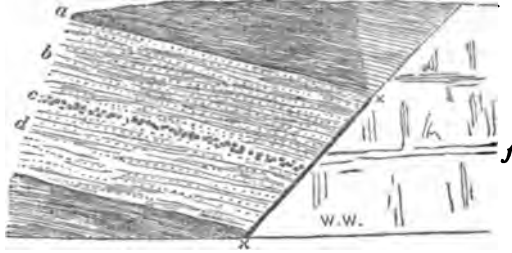
On the high ground, about a mile and a half S.E. of Hemel Hempstead, there is a faulted Tertiary outlier, against which there abuts, on the north-west, a large mass of brick-earth.

There were here two brickyards, the more northerly one worked for the brick-earth chiefly; but at the southern part, near the road, the older beds were shown; and I saw the following section of them in 1864:—

	FEET.
Basement-bed of the London Clay. Brown loam with a bed of pebbles near the top	about 6
Reading Beds { Slate-coloured plastic clay, passing into the bed below	" 6
{ Slightly sandy clay, green, mottled with crimson, yellow-stained at the bottom	" 3
{ Green clayey sand, mottled red; more clayey at the bottom of the pit	" 3

In the year 1861 the pit at the southern brickyard was cut back until chalk was suddenly touched, and not below, but abutting against the Tertiary beds. The outlier had been mapped some time before, I think in 1859, by my colleague the late MR. R. TRENCH, who told me that the Tertiary beds here seemed to be disturbed, and were in a sort of hollow in the Chalk; but who saw nothing to show that there was a fault. My attention was drawn to the section by my friend DR. J. EVANS, who was kind enough to go with me to the spot. The beds, which dip at an angle of about  $15^{\circ}$  towards the fault, were as in Fig. 36.

Figure 36. Diagram-section of a Pit near Bennets End.



- |              |   |               |   |   |   |                |
|--------------|---|---------------|---|---|---|----------------|
| London Clay. | { | Basement-bed. | { | <i>a</i> Roughly laminated brown clay, from 0 to about 6 feet.  | } | about 12 feet. |
|              |   |               |   | <i>b</i> Brown loam, with fossils, over 6 feet;<br><i>c</i> Flint-pebbles with many oyster-shells, mostly well-preserved and often with both valves together, about 6 inches -<br><i>d</i> Brown loam like <i>b</i> , but with fewer fossils, 5½ feet |   |                |

*e* Bluish-grey plastic clay of the Reading Beds, holding water.  
*f* Chalk, abutting against the basement-bed of the London Clay.  
 x x Layer of clay along the fault.

The right-hand part of the figure (which is lightly engraved) was not actually to be seen. I have drawn it in order that the fault, of the occurrence of which there can be no doubt, may be more clearly understood.

The hade of the fault was about 50°. The surface of the chalk was very hard and smooth, and along it there was a layer of clay with "race"; it was not cut through. I was told that the wall, so to speak, of chalk continued in a straight line nearly N. and S., which would therefore be the direction of the fault.

In 1864 I again visited Bennet's End, in company with DR. EVANS, and found the section figured above abandoned, and the fault hidden. However a new pit had been dug a little to the west, showing a smaller fault, with its downthrow in the same direction, throwing the London Clay against the basement-bed, and giving the following section:—

- |               |   |   |
|---------------|---|---|
| London Clay.  | { | Brown clay, with a flint-pebble here and there.   |
|               |   | Basement-bed. Light-brown loam, 12 feet or more thick, with a little "race"; the pebbles a little above the middle, and with a thin bed of very friable shells in sand, about 2 feet below them. At one part a layer of blocks of calcareous sandstone from a foot to 2 feet from the bottom. |
| Reading Beds. |   | Bluish-grey and yellow-stained plastic clay, about 8 feet shown.  |

The boundary of the area of the Reading Beds mapped on the eastern side of the fault (the downthrow of which is on the west) is very doubtful, owing to the quantity of brick-earth over that part: indeed it is not unlikely that there may be nothing but the latter above the Chalk; the outlier, in that case, being altogether cut off on the east by the fault.

DR. EVANS tells me that by the roadside just eastward of The Hyde (N.W. of Abbot's Langley), light-coloured sand has been found. This is most likely a pipe of the Reading Beds.

There is a small outlier at Bedmont, about a mile north of Abbot's Langley. There seems to be clay beneath the thick gravel at the northern end of the



village, where there is a pond, and at the other end, along the road to Abbot's Langley, is a little mottled clay.

A like unsatisfactory patch of the Reading Beds occurs at Abbot's Langley. Something very much like mottled clay is shown on the road about a quarter of a mile S.E. of the church; and there is a slight but marked rise of the ground round the greater part of the outlier. DR. EVANS pointed out to me a very small ill-marked swallow-hole on the southern side of the road, about a third of a mile S.S.W. of the church. The wells in the village are shallow, which is confirmatory of there being some small thickness of the Reading Beds below the gravel.

MR. DICKINSON noticed, many years ago, that this village is on "a bed of gravel overlying a natural basin of clay," so that "water poured over the sides of the basin . . . and numerous springs were formed . . . after a wet season, and the springs were invariably dried up in the summer."\*

At St. Alban's is a thin patch of the Reading Beds (half in and half out of our district) with a doubtful boundary, and which most likely ends, on the south, a little below the cross-roads at St. Peter's. In a field beyond the houses N.W. of that church I saw some sand below gravel in a small old pit; and at the southern end of Bernard Heath, over a quarter of a mile a little E. of N. from the church, was an old chalk-pit, showing at the top flint-pebbles in brown clay, which may perhaps be the bottom bed, discoloured and altered by exposure.

The only clear section was in the brickyard at the northern end of Bernard Heath, where there was to be seen at one part (in 1860) more than 20 feet of brickearth (below which gravel has been found), white and clayey at the lower part; with a few small pebbles of flint and of white quartz; whilst close by and at the same level a small pit showed the following beds:—

Gravel.

Reading Beds.	{	White and buff sands, with a very few small flint-pebbles, over 8 feet.
		Bottom-bed; about 2 feet.

Chalk.

I could not get at the bottom-bed; and its thickness was not clearly shown.

On the hill top S.W. and S. of Hill Farm, and a little more than four miles south of St. Alban's, there is a small patch of the Reading Beds, barely separated from (if, indeed, it does not join on to), the spur of the main mass at Newland. The Reading Beds are for the most part hidden by pebbly brick-earth, the only section of the former being in the road-cutting about a third of a mile south of Hill Farm, along which, going from the N.E., chalk, covered only by drifted loam &c. is shown a little way below the top of the hill; whilst higher up light-coloured sand with layers of clay comes on, and still higher there is green clayey sand mottled with red, the lower part more sandy, and passing downward into light green-grey sand. At the highest part of the road there is pebbly brick-earth and a little red-mottled plastic clay, which latter most likely passes downward into the red-mottled clayey sand. Down by the same road on the other (south-western) side the Reading Beds are much hidden by brick-earth.

It is possible that near Camp Row, north-eastward of Aldenham, there may be patches of mottled clay below the gravel that spreads over the high ground.

In the cutting on the high road, more than half a mile south of Colney Street, and just above the lane turning off to Wild Farm, there is a rather large pipe of the clayey greensand of the bottom-bed. The Chalk comes to the surface higher up, but is soon succeeded by the main mass of the Reading Beds.

More than three miles to the east, on the southern side of the high road, between South Mims and Ridge Hill, there is a sand-hillock, almost surrounded by, and nearly joining on to, the main mass.

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\* *Proc Inst. Civ. Eng.*, vol. xiv. p. 71. (1855.)

FOSSILS.

*Bottom-bed.*

Green sand, Croydon. Authority H. M. KLAASSEN, *Proc. Geol. Assoc.*, vol. viii., no. 4, pp. 229, 230, (see above, p. 131).

Crocodylian tooth.

Lamma contortidens, <i>Ag.</i>	Tooth of Edaphodont fish.
Otodus obliquus, <i>Ag.</i> (and another form).	Fish vertebræ and teeth.

Cardium.	Perna croydonensis, <i>Newton</i> .
Nucula.	Pholadomya.
Ostrea bellovacina, <i>Lam.</i>	

Hoploparia gammaroides, *M'Coy* Crustacean.  
not from Mr. Klaassen's list, but in Serpula.  
DR. A. CARPENTER'S collection.

Plants, silicified stems.

*Estuarine Shell-beds.*

As our district includes the chief fossiliferous localities of the shell-beds, with the exception of Upnor, which is but little to the south, the following list has been made a fairly perfect one for that part of the formation by including Upnor amongst the localities, which are marked by numbers, as follows :—

1. *Dulwich*.—Effra Branch Sewer. Chiefly from the list of C. RICKMAN, *Quart. Journ. Geol. Soc.*, vol. xvii., p. 6.
2. *Peckham*.—C. RICKMAN, *Proc. Geol. Assoc.*, vol. i., no. 6, p. 112.
3. *New Cross*.—Counter Hill and Cutting on the London and Brighton Railway. PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. x., p. 105, and Geological Survey collection.
4. *Lewisham*.—Loam Pit Hill. Collected by MR. J. G. GOODCHILD.
5. *Charlton*.—PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. x., p. 102.
6. *Erith*.—The large sand-pit. Collected by MR. J. G. GOODCHILD.
7. *Croydon*.—H. M. KLAASSEN, *Proc. Geol. Assoc.*, vol. viii., no. 4, pp. 236-242. (1883).
8. *Chiselhurst*.—From my own collecting, and from specimens collected for the Geological Survey by R. GIBBS, and determined by R. ETHERIDGE.
9. *Upnor*.—PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. x., p. 108, and Geological Survey collection.

In some cases, chiefly as regards Dulwich, additions have been made from S. V. WOOD'S "Eocene Bivalves," *Paleontograph. Soc.*

MAMMAL.									
Coryphodon croydonensis, <i>Newton</i>	-	-	-	-	-	-	-	-	7
Coryphodon	-	-	1	-	-	-	-	-	7
Bones	-	-	1	-	-	-	-	-	
BIRD.									
Gastornis Klaasseni, <i>Newton</i>	-	-	-	-	-	-	-	-	7
REPTILES.									
Chelonian bones	-	-	-	1	-	-	-	-	
Crocodylian scutes	-	-	-	1	-	-	-	-	
Trionyx	-	-	-	-	-	-	-	-	7

## FISH.

Lepidosteus (vertebræ) -	-	-	-	-	-	-	-	-	9
Bones, scales, teeth, vertebræ -	-	-	1	-	3	-	-	6	9

## MOLLUSCA.

## Gasteropoda.

Bulimus rillyensis, <i>Desh.</i> -	-	-	1						
Calyptræa trochiformis, <i>Lam.</i> -	-	-	1	2	3				
Cerithium funatum, <i>Mant.</i> (including									
<i>C. variabile, Desh.</i> ) -	-	-	1	2	3	-	5	6	7 8 9
Fusus latus, <i>Sby.</i> -	-	-	-	-	-	-	5		
" sp. -	-	-	1						
Hydrobia Parkinsoni, <i>Mor.</i> -	-	-	-	-	3	-	5	6	- 9
" Websteri, <i>Mor.</i> -	-	-	-	-	3?	-	6		
" sp. -	-	-	-	-	-	-	-	7	8
Melania inquinata, <i>Defr.</i> -	-	-	1	2	3	4	5	6	7 8 9
Melanopsis buccinoides, <i>Fer.</i> -	-	-	-	-	3	-	5	-	7 9
" sp. -	-	-	1	-	-	-	5	6	- 8
Neritina consobrina, <i>Fer.</i> (? also entered									
as <i>N. pisiformis, Fer.</i> ) -	-	-	-	-	-	-	5		
Neritina globulus, <i>Defr.</i> -	-	-	-	2	3	-	5	-	7
" jaspidea?, <i>Desh.</i> -	-	-	1						
Paludina aspera, <i>Mich.</i> (? = <i>P. Desnoyeri,</i>									
<i>Desh.</i> ) -	-	-	1						
Paludina lenta, <i>Brand.</i> -	-	-	1	-	3	-	-	-	8
" " var $\beta$ , <i>Mor.</i> -	-	-	1	2	3	-	-	-	8
" sp. -	-	-	-	-	-	-	-	7	
Pisania, sp. -	-	-	-	-	-	-	6		
Pitharella Rickmani, <i>Edw.</i> -	-	-	1	2	-	-	-	-	8
Planorbis hemistoma, <i>Sby.</i> -	-	-	-	-	-	-	5	6	- 9
" lævigatus, <i>Desh.</i> -	-	-	1	2	3	-	-	-	
" sp. -	-	-	-	-	-	-	-	7	
Rissoa -	-	-	1	2	3	-	5		

## Lamellibranchiata.

Arca (Byssarca) Cailliaudi, <i>Bellardi</i> -	-	-	1	2					
" depressa, <i>Sby.</i> -	-	-	-	-	3				
" dulwichiensis, <i>Edw.</i> -	-	-	1						
" sp. -	-	-	-	-	3				
Corbula regulbiensis, <i>Mor.</i> var. -	-	-	-	-	3				
" sp. -	-	-	1						
Cyclas? (small bivalve) -	-	-	-	-	-	-	-	-	8
Cyrena anceps, <i>Wood</i> -	-	-	1						
" cordata, <i>Mor.</i> -	-	-	1	-	3	4	5	6	7 8 9
" cuneiformis, <i>Fer.</i> -	-	-	1	2	3	4	5	6	7 8 9
" dulwichiensis, <i>Rickman</i> -	-	-	1	-	-	-	-	7	8
" Forbesii, <i>Desh.</i> -	-	-	-	-	-	-	5		
" pullastra, <i>Wood?</i> -	-	-	1						
" tellinella, <i>Fer.</i> -	-	-	-	-	3	-	-	6	
" trigona, <i>Desh.</i> -	-	-	1						
" tumida, <i>Wood</i> -	-	-	1						
Modiola Mitchelli, <i>Mor.</i> -	-	-	1	-	3	-	-	-	8
Mytilus? -	-	-	-	-	3				
Nucula fragilis, <i>Desh.</i> -	-	-	-	-	-	-	5	-	7
" sp. -	-	-	-	-	3				
Ostrea bellovacina, <i>Lam.</i> (including									
<i>O. edulina, Sby.</i> ) -	-	-	1	2	3	4	5	6	7 8 9
Ostrea pulchra, <i>Sby.</i> -	-	-	1	-	-	4			
" tenera, <i>Sby.</i> -	-	-	1	-	3	-	5	6	7 8 9
Pectunculus plumsteadensis, <i>Sby.</i> -	-	-	-	-	-	-	-	7	
" terebratularia, <i>Lam.</i> -	-	-	-	-	3				
Scrobicularia (Psammobia) Condamini,									
<i>Mor.</i> -	-	-	-	-	3	-	5	-	-

Scrobicularia (Psammobia) dulwichiensis,									
Wood -	-	-	-	1					
Teredina personata, Desh.	-	-	-	1					
Unio Edwardsi, Wood	-	-	-	-	2				
„ Michaudi, Desh.	-	-	-	1					
„ subparallela, Edw. (= U. Deshayesii, Prestwich)	-	-	-	1	2	8	-	-	-
Unio, sp.	-	-	-	-	-	-	-	6	7
								8	9
Polyzoon (Flustra)	-	-	-	1					
CRUSTACEA (Entomostraca).									
Candona Richardsoni, Jones	-	-	-	-	-	-	-	5	
Cypris or Cythere	-	-	-	-	-	3	-	5?	-
								-	9

*Leaf-beds.*

PLANTS. *Lewisham and Counter Hill* (unless otherwise stated). J. S. GARDNER, *Palæontograph. Soc.*, with some additions, kindly made by MR. GARDNER.

*Aralia?* leaf.

*Carpolithes* (*Rhytidosporum*, *Hooker*) ovulum *Brongn.*

*Lygodium* [*Pteris*] *Prestwichii*, *Ett. and Gard.* Leaf-bed and lignite-bed; also at Croydon and at Dulwich.

*Libocedrus adpressa*, *Gardner*, from the leaf-bed of Widmore, Bromley.

Leaves, seed-vessels, and wood were also found at Dulwich.

*Liriodendron Gardneri*, *Sap.* Dulwich.

*Palmetto*, Croydon.

*Platanus*, Widmore (Bromley).

*Pteris*, Croydon.

MR. GARDNER has kindly given me the following sketch of his views as to the correlation and succession of the various leaf-beds in the Lower London Tertiaries, and has asked me to print it, in order to "help plant-collectors out of a good deal of confusion." He says that "if you class the striped beds of Loam Pit Hill or Counter Hill (Lewisham) with the Woolwich Beds, you must also class the Widmore beds with the same" (letter of August 1888).

Striped beds of	{	Lewisham	}	Oldhaven
		Widmore (Bromley)		or
		Coldham (S. of Winchester)		Woolwich Beds.
Lignitic clays of	{	Lewisham	}	Woolwich Beds.
		Dulwich		
		Croydon		

Newhaven, Reading, and Newbury. Reading Beds (the first rather newer than the others).

With regard to the Coldham beds (loam), in which I was the first to find plant-remains, it is perhaps right to record my own opinion that they belong neither to the Oldhaven nor to the Woolwich Beds, but to the basement-bed of the London Clay.

My colleague MR. GOODCHILD, who has given much attention, of late years, to the sections near Woolwich and Lewisham, is disposed to class the "striped sands," or the leaf-beds, with the Blackheath rather than with the Woolwich Beds.

The question is of interest as showing the difficulty that is sometimes met with in attempting to be precise in such points.

## CHAPTER 14. LOWER LONDON TERTIARIES (BLACKHEATH, OR OLDHAVEN, BEDS).

### GENERAL REMARKS.

Whilst this division is clearly separable from the Woolwich Beds below, it is also distinct from the London Clay above, and I think cannot fairly be classed as the "basement-bed" of the latter, using that term in its strict sense (as a peculiar bed at the bottom of and belonging to that formation). The use of the term "basement-bed" (not wholly in the sense above mentioned, but also for a set of deposits next below the London Clay and separable from it) seems to me likely to mislead (indeed I was misled by it myself) and therefore it should be given up. Moreover, the true basement-bed of the London Clay may sometimes be seen overlying the group for which the name "Oldhaven and Blackheath Beds" has been proposed.

Were these beds intercalated either with the London Clay or with the Woolwich Beds, they would of course be classed with the one or with the other: but it is not so; they always come between the two.

In this Memoir, referring to a district where the pebbly condition is almost universal, the term Blackheath Beds is preferable to that of Oldhaven Beds, the latter having been first applied to the marine sands of East Kent.

In 1838 DR. J. MITCHELL drew attention to these pebble-beds,\* remarking that "on Blackheath, and over a considerable district in the county of Kent, and a small portion of Surrey, there are most extensive and deep beds of a peculiar kind of flint . . . . The designation of Blackheath flint is proposed for it as involving no theoretical opinion." I have therefore only followed this author in using the name Blackheath Beds, as representing fact without theory. The shrewd observer quoted then goes on to note the area over which the pebble-beds occur, tracing them from Croydon by Addington to Hayes, about Bromley, Chiselhurst and Bexley, and from Erith to Plumstead and Blackheath. Not only however does he thus accurately describe their main area of outcrop; but he also notices their occurrence (as outliers) to the east, near Shorne, and on the Chalk range to the south, above Godstone, thus forestalling the work of the Geological Survey. This author's error in classing the pebble-beds of Warley (Essex) and of St. Ann's Hill (Chertsey), which belong to the Bagshot Series, with the Blackheath Beds is a natural one, considering the state of Tertiary geology at the time he wrote, for the two deposits are exactly alike.

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\* *Mag. Nat. Hist.*, n. ser., vol. ii, pp. 218-221.

By some mischance I failed to notice this paper in the Memoir on the London Basin (vol. iv.) and am glad to have the chance of repairing the omission.

### *Structure.*

In composition this Series is simple, consisting as it does almost wholly of perfectly rolled flint-pebbles in a fine sandy base, or of fine sharp light-coloured quartz-sand.

On the south-east of London the pebbly state holds, and generally shows current-bedding, but sand often occurs in more or less irregular masses. Sometimes the pebble-beds are cemented into a hard rock; they are often fossiliferous, and generally thick.

The most remarkable thing about the beds of flint-pebbles is the extent to which the pebbles have been worn. The shingle of our south-eastern coast nearly always contains flints in many states, from the rough nodule, that has but lately fallen from the chalk-cliff, to the well-rounded pebble; but in this deposit all are finished specimens, at least it is very rarely indeed that anything like a subangular flint is to be seen. From this difference it would seem that these old pebble-beds were not formed as a beach along a chalk-shore, as in that case they should contain many flints but partly worn, and one is led therefore to infer that they must have been deposited some way off the shore, as a bank to which no flints could get until after having been long exposed to wearing action.

The fossils of these beds are partly estuarine and partly marine, sometimes much the same as those of the Woolwich Beds below, and sometimes more nearly approaching those of the London Clay above, seeming therefore to prove oscillations of surface or changes of current and nearness to land, conditions which might also be expected from the masses of pebbles.

### *Junction with the Beds below.*

In the eastern part of Kent, where the upper part of the Woolwich Beds seems to be absent, it is strange that the Oldhaven Beds rest evenly on the sand of the former, showing what may be called an accidental conformity; whilst on the west, where these Woolwich Beds are more fully developed, they are cut into most irregularly by this overlying Series; often so much so that nothing but the pebbly greensand (bottom-bed) is left, and sometimes not even that, the Blackheath Beds having scooped down to the Thanet Sand. In some outliers far out in the Chalk-tract the overlap goes beyond this indeed, and the Blackheath Beds rest at once on the Chalk.

The occurrence of outliers of the Tertiary beds near the edge of the Chalk-escarpment, in Surrey and Kent, does not prove any unconformity between the Chalk and the Tertiary beds, but rather one between members of the latter, for the outliers in question do not consist of the lowest Tertiary formation, the Thanet Beds.

As there seems to be some constancy in this transgression of the Blackheath Beds over the other divisions of the Lower London Tertiaries toward the North Downs (a movement begun indeed by the Woolwich Series, which seems to overlap the Thanet Beds to some extent, though not so markedly as the highest division overlaps both) one is warranted in concluding that the planing down of the Chalk that once spread over the Wealden tract began in Lower Eocene times, and that the pebble-beds of Bromley, Blackheath, &c. are one of the direct results of that denundation.

#### DETAILS.

##### *Between the Wandle and the Ravensbourne.*

Along the southern boundary of the London Basin the most westerly place where the Oldhaven Beds are seen is Croydon, beyond which they seem to thin out.

The boundary-line through that town is hidden of course, and not only by reason of the buildings, but also by the gravel; but it seems to run across the London and Brighton Railway to Park Hill.

The line of outcrop is also hidden, but an inward spur seems to run northward under the gravel to Selhurst, where the beds rise up slightly, and, being free from gravel, are to be seen in sections.

The outcrop of this formation at Selhurst may however be divided from that of the main mass on the south by a capping of London Clay, under the gravel of Croydon Common, and in this case it would of course be an "inlier," surrounded on all sides by London Clay. The wide spread of gravel makes this uncertain, although one may be sure that this outcrop (so far within the general line of the boundary of the London Clay, and not at a very low level) is owing to some local uprise of the beds.

Between Park Hill and Shirley the boundary-line is irregular, and some of the field-sections show the bottom of this Series to be a shell-rock, many pieces of which lie scattered over the ground.

From Shirley round the hill to Addington, the boundary-line follows closely that of the Woolwich Beds; in some places indeed these seem to be quite overlapped by the Blackheath Beds (see p. 132). Then it winds downward to the Ravensbourne at Hayes.

Between Addington and Beckenham the outcrop is broad, the dip and the ground-slope going together, but broken by some outliers of London Clay.

##### *Croydon.*

In the railway-cutting on the western side of the high road at West Croydon Station fine sand crops out from below the thin clayey pebble-bed, which here forms the basement-bed of the London Clay.

The cutting at the Thornton Heath Station, on one of the lines of the London and Brighton Railway, was much hidden when I saw it, in April 1863,

although the line had not long been open. The northern end is in London Clay, but on the eastern side a few yards north of the station, an almost white sand, at one place with a large block of fossil-bearing calcareous sandstone, rises up from below. The bottom part of the London Clay is roughly laminated, as usual, and at the base are a few flint pebbles. The junction with the sand is sharp and dips sharply along the line northward. Southward, by the station and the bridge, to the foot-bridge, where the cutting is shallow, there is also sand below the clay, in great part however only shown by the gutter below the level of the rails. Beyond the foot-bridge there is clay only, and the cutting is very shallow; but just before reaching the next bridge the sand comes up to the surface.

The fine light-coloured sand also occurs at the brickyard just westward of Thornton Heath Station, where however it is capped by gravel and clay, and in a small pit on the other side of the line, between it and Railway Road, there was (in 1870) an irregular capping of London Clay over the sand.

In two wells, about 200 yards apart, about a quarter of a mile southward of Thornton Heath Station, beneath loamy gravel, 18 feet thick, there was found a bed of calcareous sandstone, up to 8 inches thick, with oyster-shells and plant-remains, according to information given.

In the large brickyard between White House Farm and Selhurst, the higher pits show London Clay only, the upper part brown (discoloured by oxidation), and with septaria; the lower part a little sandy, bluish-grey, brown and yellow (ochreous), roughly laminated, and with many crystals of selenite. Lower down a pit showed from 7 to 10 feet of that formation, grey and laminated, with a few flint pebbles at the bottom, resting almost evenly on nearly white sand, of which not more than 10 feet was to be seen, the bottom of the pit being filled with water. The junction was sharp and showed a slight northerly dip. At another pit, near this and at the same level, from 16 to 18 feet of the sand were said to have been sunk through, below the London Clay, and then hard blue clay with shells (Woolwich shell-bed) was found. In this last pit, which is by the side of the lane to White House, all that could be seen when I was there, many years ago, was a brown clayey drifted sand (with a few small flint-pebbles and subangular flints at the bottom, and a thickness of about five feet at the most) over London Clay.

In 1870 the pits were of course different, but showed the same beds, and also some small faults, the junction being well exposed.

In a small pit at the back of some new houses a little southward of the above brickyard, I again saw London Clay, two or three feet thick and with pebbles at the base, over white sand.

In an old pit in the ground surrounded by Oval Road, a little N.E. of East Croydon Railway Station, the section was as follows, in 1870:—

Valley Gravel, of subangular flints and flint-pebbles, about 8 feet.

Blackheath pebble-bed. Black flint-pebbles in sand, proved to a depth of 10 feet.

South of the Addiscombe Road there are plentiful signs of the pebble-beds, whilst on the north, when the grounds of the late Military College of the East India Company were being laid out for building-purposes, many sections were made, both in pebble-beds and sand.

The sections at Park Hill have been described at pp. 129–131.

Eastward of the Water Tower at Croydon is a small outlier, and above Combe Farm a smaller, a little shell-rock resting irregularly on the clay of the Woolwich Beds.

Near the lodge at the eastern edge of Shirley Park there was a pit in a fine pebble-bed, false-bedded in a westerly direction.

By the roadside a little west of the Addington sand-pits a small pit showed a pebble-bed over sand with patches of pebbles, and another pebble-bed occurred in the road (just below).

South-westward the boundary-line is marked by springs and ponds.

The high ground of the Addington Hills is formed by the pebble-beds, in which there are pits.



In the sand-pit marked on the old Ordnance Map about a mile N.W. of Addington, there is white and buff sand, with thin layers of pale clay here and there, and a few layers of pebbles in the upper part. I was told that pebbles had been found below the sand, and that in a well at the brewery just below (to the north) the Chalk was reached at a depth of 70 feet.

In a nearly overgrown pit in Addington Park, about half a mile W.N.W. of the church, there was light-coloured sand, with a very few small flint-pebbles.

Another pit about the same distance N.N.W. from the church was in both sand and sandy pebble-beds, many of the pebbles being very large.

Six feet of fine sand, with thin layers of clay in the upper part, may be seen in a small pit at a farm about a third of a mile north-eastward of Wickham Rectory.

Two of the outliers of the Woolwich Beds on the spur of Thanet Sand south of the Addington Hills have cappings of the pebble-beds, in which there was a pit in the more westerly patch, in the midst of a wood.

#### *Beckenham.*

Turning now to the northern part of the outcrop, at about a quarter of a mile N. of Beckenham Church, and on the western side of the road, there was a pit in the pebble-beds, the lower part showing masses of fossil-bearing pudding-stone.

In a pit (since given up) about half a mile S.S.W. of the church the following beds were shown in 1859:—

Pebble-bed, from 2 to 5 feet thick, resting evenly on the bed below.

Brown sand, with a few thin layers of clay, about 3 feet.

White sand, with a little brown sand, and a few flint pebbles, not more than 8 feet shown.

The cutting of the London Chatham and Dover Railway at Beckenham Station gave a good section of the Blackheath Beds, and of the bottom part of the London Clay. Although a great part of the cutting was overgrown when I saw it (in 1859 and since), I was able to make out pretty clearly the order and character of the beds.

West of the station the section, then shallow, was still open, and showed a few feet of the pebble-beds, resting slightly irregularly on sand.

A little E. of the station there is also sand, with a thin bed of flaggy fossil-bearing calcareous sandstone, which showed a small westerly dip. Eastward this stone seemed to thicken, and to contain more and more flint pebbles, until at last it becomes a shelly conglomerate. At one part there were lying about some pieces of a blue shaly bed, with *Ostrea* and *Unio* (shell-bed of the Woolwich Series), which must have come from below the sand.

By the next bridge (to the east) there is *in place* a block of conglomerate, or pudding-stone, 10 feet thick and more than 20 feet in greatest length. This continues as a bed, though perhaps with less thickness, from this spot nearly to the next bridge, where the Blackheath Beds sink below the level of the line. There are very many masses of pudding-stone jutting out from the side of the cutting.

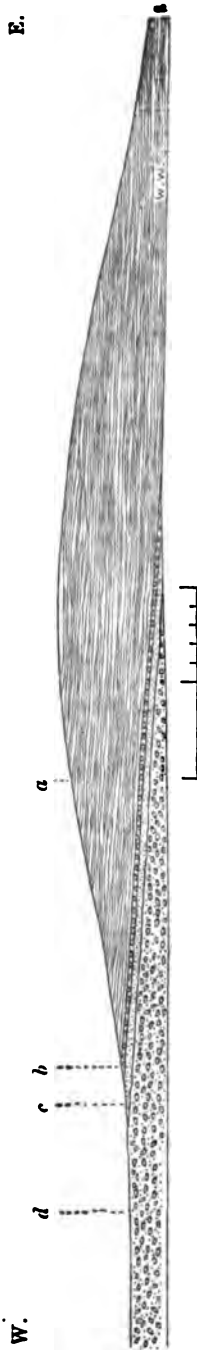
I noticed by the side of the rails, some masses of sandy earth, in which, besides larger shells, were found also some of the small *Hydrobia*, and also a specimen of a beautifully marked *Neritina*. I think that this earth came from the softer part of the pebble-bed.

The order of the beds above the conglomerate is shown in fig. 37, and a list of the fossils from it is given at pp. 236, 237.

#### *Between the Ravensbourne and the Cray, south of the Bexley Valley.*

On the right, or eastern, bank of the Ravensbourne the boundary follows that of the Woolwich Beds, along the Bromley Inlier, from near Bromley Hill House southward, and then runs a little up the side-valley south of the town, apparently not going further up the main valley.

Figure 37. Section of Part of the Cutting on the London Chatham and Dover Railway east of Beckenham Station.



Horizontal scale, an inch to 55 yards. Vertical scale about twice as great.

London Clay. { *a.* Brown and bluish-grey clay, with small crystals of selenite.

{ *b.* Basement-bed. Pebble-bed, about a foot.

Blackheath Beds. { *c.* Light-coloured sand.

{ *d.* Conglomerate of black flint-pebbles in a matrix of calcareous sandstone, with many shells.

The main (southern) boundary seems to cross the valley of the Ravensbourne at Hayes; whence, after running up the eastern side of the valley, it follows closely that of the Woolwich Beds along the steep hill-side to Holwood Park, rising gradually, with the ground.

From its highest point in Holwood Park the boundary sinks eastward to a lower level, at Farnborough, whence, sinking northward, it follows that of the Woolwich Beds along the left side of the Cray, but is of a rather more winding nature in most parts.

The Blackheath Beds have here a broad outcrop, as the ground rises southward, in the reverse direction to the dip, from the London Clay tract; there are however outliers of the latter formation, mostly of fair size.

Along the southern boundary of this tract there are sections over Hayes and Keston Commons, both in pebble-beds and sand, but none calling for notice.

In an old chalk-pit a little N.E. of Nash Farm, on the south of Hayes Common, the following section was to be seen in 1860:—

- { Brown and grey sand; 8 to 10 feet;
- { Ferruginous conglomerate of flint-pebbles; 2 to 3 feet;
- { Brownish loam; 1 to 2 feet;
- { Black-coated flints.
- Chalk.

The Beds above the Chalk can hardly be classed with the Thanet Sand, which is very unlike them; neither can they belong to the Woolwich Beds, as there is here a fair thickness of Thanet Sand between that formation and the Chalk. They may perhaps be a local Drift, or they may be owing to the scooping of the Blackheath Beds through the Woolwich and Reading Series and the Thanet Sand.

When I saw this section a second time, in 1870, it was much overgrown and somewhat different. Just above the Chalk I found a long mass of a whitish earthy mineral, which was thought to be *Websterite*, and was noticed as such.\* Feeling some doubt as to this determination, from a comparison of some small pieces of the mineral with others of *allophane*, from Charlton, I submitted the former to Mr. W. H. HUDLESTON, who wrote to me that "the substance is not *Websterite*. It is a hydrous silicate of alumina allied to *allophane*."

At the Bromley (or Farnborough) Union from 15 to 20 feet of sand has been found in tanks, &c. above the shelly clay of the Woolwich Beds.

Three small outliers occur near the main mass. There is a hillock of pebbles, but barely divided from the main mass, a third of a mile N.E. of Holwood House; at Starts Wood, just north of Farnborough, there seems to be a small outlier; and the highest part of the railway-cutting near Orpington Station passes through a small patch of sand (see p. 135).

#### *Bromley.*

Turning to the inner, or northern, part of the broad outcrop, the sections around Bromley may be described first.

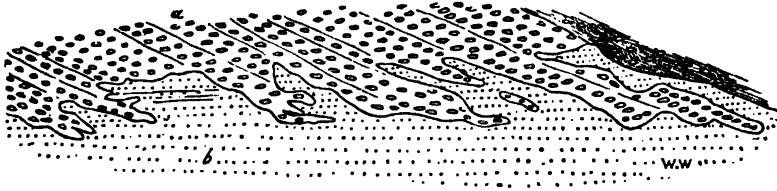
At Bromley Hill, southward of the house and low down the slope, there are both pebble-beds and sand, the latter with clayey layers, whilst further south a large and deep pit has been dug in the former, and northward, on the other side of the high road, a pebble-bed and conglomerate have been found above sand.

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\* *Memoirs*, vol. iv. p. 243. (1872.)

The cutting at the Bromley Station shows a great thickness (from 20 to 30 feet) of the pebble-bed, with light-coloured sand below. The former is markedly false-bedded, the dip of the current-bedding being about  $25^{\circ}$  E.; but the pebbles for the most part having the longer axis nearly horizontal, and thus showing that it is not a true dip of the beds; for the longer axis of the pebbles should be in the line of dip. The junction of the pebble-bed and the sand is remarkably irregular, the pebbles running far into the sand in wedges and veins, as shown in fig. 38 from a sketch taken at the eastern end of the northern side of the cutting.

Figure 38. Junction of Pebble-beds and Sand at Bromley Railway Station.



a. False-bedded pebble-beds.

b. Sand.

At the Bromley gasworks the following beds were found :—

Loamy gravelly soil; about 2 feet.  
 Buff sand - " 25 "  
 Rock-bed (conglomerate).

In the well here (see Well-sections, *post*) chalk was reached, but the division between the Blackheath and the Woolwich Beds is not determinable.

The section at Widmore Kiln was very clear at the end of the year 1870, when the deep pit at the northern end gave the following section, the higher beds occurring only at the eastern and higher side, where they were preserved from denudation by having been thrown into the form of a trough or hollow. Fig. 39 is from a sketch of this pit made by my former colleague, Mr. F. RUTLEY, in 1871.

Soil.		FEET.
1. London Clay.	Grey and brown weathered clay, at most Basement-bed: clayey pebble-bed, the pebbles of black flint	$3\frac{1}{2}$ $\frac{1}{2}$ to $\frac{1}{2}$
2. Oldhaven Beds.	Light-coloured (mostly nearly white) sand; with a few pebbles in the upper part, chiefly in one broken layer, and a few thin clay-layers; below 8 feet from the top these last are in force	12 or more.
	3. Dark bluish-grey clay, laminated, with a few very thin sandy layers, small pieces of leaves, wood (in the state of lignite) and iron-pyrites	about 9
Oldhaven (or Woolwich) Beds?	4. Sand with layers of clay in fine alternations. At one part (in the trough) the top highly ferruginous; at another it seems to pass up into the clay, the lower part of which is then more sandy. Tabular concretionary masses of sandstone occur a few feet down, and still lower many good impressions of leaves have been found (see p. 213). Not bottomed	26 or more.

Figure 39. Pit at Widmore Kila, Bromley. (F. RUTLEY.)



1. London Clay.      2. Sand.      3. Dark Clay.      4. Sand and Clay.      x Leaf-bed (on the left).



At some new houses just south of Bickley Station I saw, under a few feet of brown loamy sand, a bed of very small pebbles, a regular pea-gravel indeed.

The long railway-cutting at Bickley Station is in the false-bedded pebble-beds, above which however the London Clay comes on at the eastern end. The section shown by this part of the cutting is interesting, as the London Clay was seen to lie somewhat irregularly on the Blackheath Beds, and the basement-bed of the former was seen above the sandy pebble-bed, here classed with the latter formation. Fig. 40 is a representation of the northern side of this section: the other side was not so clear, and in one part, near the eastern end, the basement-bed seemed to be absent, the topmost part of the otherwise sandy pebble-bed below being there made somewhat clayey by infiltration from the clay above; the false-bedding however was not destroyed, and the distinction from the irregular confused clayey pebble-bed that near by forms the basement-bed was not lost.

Just south of the railway, and about three quarters of a mile east of the Bickley Station, a brickyard was open in 1863, and the small pit at the highest part was in the London Clay alone, whilst another just below showed the following beds:—

London { Clay, but little to be seen.

Clay. { Basement-bed: a clayey pebble-bed, 8 or 10 inches.

White and light-coloured sand of the Oldhaven Beds, 3 feet shown.

This section is no very great way from the eastern side of the cutting, where we have just seen that the basement-bed is underlain by a thick sandy pebble-bed, the sand being absent. This seems to give further evidence against classing the sandy pebble-bed with the basement-bed of the London Clay.

A small pit on the eastern side of the road little more than a mile E.N.E. of Bromley Palace, showed pebbles over sand.

#### *Chiselhurst.*

The scenery around this pretty village is greatly owing to the presence of the pebble-beds, the spread of which, forming a broad dry level tract, has caused the commons on the higher ground both eastward and westward.

The railway-cutting north-west of Elmstead Wood gave a section from the London Clay to the Woolwich Beds, as in Figure 41, which is from a drawing of the eastern and higher side (except at the tunnel-mouth, where the other side was clearer) made in 1865. The northern part is in London Clay only.

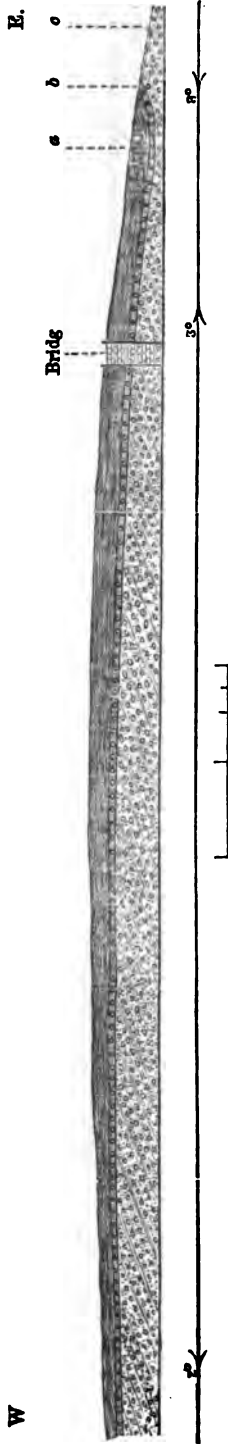
The junction of the London Clay with the Oldhaven Sand is mostly even, but in two or three places the former scoops down a foot or so into the latter.

The absence of the shelly clay of the Woolwich Beds at the southern end may be accounted for in three ways:—(1) by a small fault, with a downthrow on the south, in the hollow filled with the loam; (2) by a slight arch, by which the dip would change and the beds sink southward; (3) by the Oldhaven Series resting irregularly on the Woolwich Beds and partly cutting them off.

In making the tunnel a great quantity of Oldhaven Sand was thrown out at the shafts, and at some places it was full of fossils. MR. C. EVANS collected many of these, and published a list of them,\* which is included in the table at pp. 236, 7. What struck me as the most remarkable thing was, that whereas specimens of *Pectunculus* were of rare occurrence (I found but a single specimen) in the conglomerate of the Sundridge "rock-pit," close by, in these softer beds they are very plentiful. At the southern end of the tunnel more than 40 feet of the Blackheath Beds are cut into, as shown in Fig. 42, from a drawing of the western side (1865), and this division here rests on the bottom-bed of the Woolwich Series, the shell-beds having been eroded away.

\* Geologist, vol. vii. p. 84. (1864.)

Figure 40. Eastern End of the Cutting on the London Chatham and Dover Railway east of Bickley Station.

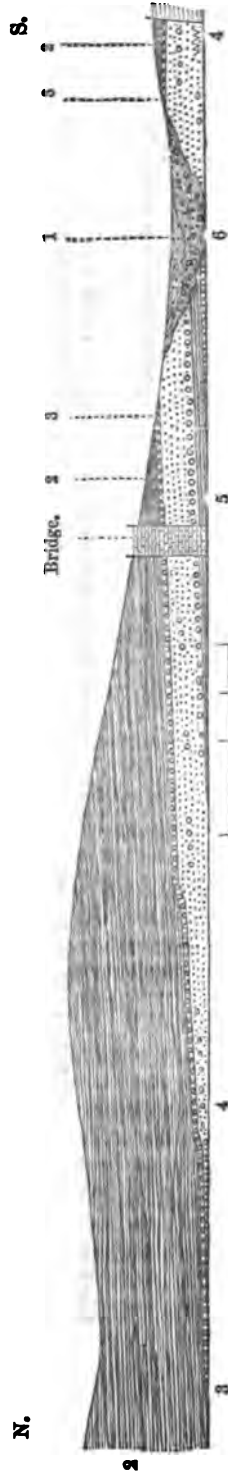


Horizontal scale about 50 yards to an inch. Vertical scale about twice as large.

	Feet.
London Clay. { a. Roughly laminated dark grey and brown clay, - - - greatest thickness about 9	9
{ b. Basement-bed. A clayey pebble-bed - - - " "	2
Blackheath Beds. c. Sandy pebble-bed; the layers of false bedding having a westerly dip of from 10° to 20° (increasing from W. to E.) - - - greatest thickness shown, 15	15



Figure 41. Southern Part of the Cutting on the South Eastern (Lewisham and Tunbridge) Railway N.W. of Elmstead Wood (Sundridge).



Horizontal scale 60 yards to an inch. Vertical scale 60 feet to an inch.

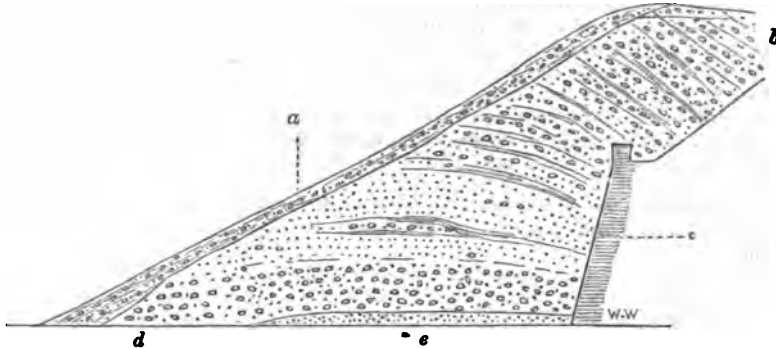
1. Drift of loam and pebbles filling a hollow.

London Clay. { 2. Clay, with septaria in the upper part, and in the lower much selenite. Mr. DALTON has got much fossil wood from here.  
3. Basement-bed. A clayey pebble-bed, from less than a foot thick to more than a foot and a half (near the bridge, where the lower part is more sandy).

4. Oldhaven Beds. Fine sharp light-buff sand with lenticular layers of pebbles, a layer at the bottom (at one part  $2\frac{1}{2}$  feet thick) and a few scattered pebbles; about 10 feet.

Woolwich Beds. { 5. Clay shell-beds. The upper part rather sandy in places; the middle part a shell-rock; the lower part dark clay, close to the bottom marly, rather hard, and with *Paludina* (= the *Paludina*-bed of Peckham, &c.), less than 3 feet.  
6. Fine light-coloured sand.

*Figure 42. Cutting at the Southern Mouth of the Sundridge Tunnel, South Eastern (Lewisham and Tunbridge) Railway.*



- a.* Pebbly talus.  
*b.* False-bedded fossiliferous pebble-bed, often hard along the planes of false-bedding.  
*c.* Light-coloured sand with a few pebbles.  
*d.* Fossiliferous pebble-bed, and sand.  
*e.* Bottom-bed of the Woolwich Series: Green sand with pebbles, 2 feet shown.  
 Slope of the hill 25°.

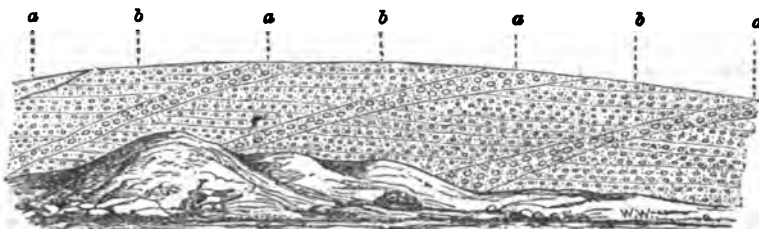
The Sundridge "rock-pit" is in the wood on the eastern side of the park and north of the brook. The upper part shows pebble-beds with beds of sand, both in great part hardened (by calcareous cement) into pudding-stone and sandstone, full of fossils (oyster-shells being very plentiful, and the other shells very fragile), and false-bedded. The lower part shows sand, with a few beds of pebbles and of shells (some in the pebble-beds), also false-bedded. I was told that 15 feet more of sand and pebble-beds had been sunk through. The whole is light-coloured, and the dip of the false-bedding varies from 10° to 25°, being greatest in the upper part, and its direction is northerly. The fossils found here are listed at pp. 236, 237.

The same sort of conglomerate-beds have been dug in the wood on the other (eastern) side of the road, where the angle of the false-bedding is again as high as 25°.

The fine section given by the short but deep railway-cutting on the south-east has already been described (see fig. 25, p. 163).

A pit by one of the new houses at the northern side of Camden Park showed, in 1870, a peculiar kind of false-bedding, oblique layers of large pebbles running through horizontal layers of small pebbles, as in fig. 43.

*Figure 43. Section in the Blackheath Pebble-beds at the Northern Side of Camden Park.*



*a.* Layers of large pebbles.

*b.* Layers of small pebbles.

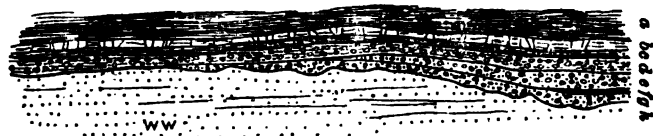
In a pit within the wood, just east of the brook through Bickley Park, and north of the new road, the lower part of the sand contains a few pebbles. Another pit on the northern side of the new road showed the brown sandy pebble-bed, 15 feet thick, resting irregularly on light-coloured Thanet Sand, seen to a depth of 8 feet, the junction sloping down towards the brook. At one part the sand next beneath the pebble-bed contains a few pebbles. The continuation of the section from this latter pit to the railway-cutting close by is shown in fig. 26, p. 164. A drift of loam and pebbles scoops into the pebble-bed, and a good thickness of it occurs on the road just above.

At the northern edge of Scaisbury Park, near the top of the hill, and about half-way between Chiselhurst and Perry Street, there is buff sand with shells, like that in the Sundridge rock-pit. There are plenty of sections in the pebble-beds and sand round Chiselhurst, from which place the level of the ground sinks north-eastward to the valley between Bexley and Southend (Eltham).

In the inlier of the Woolwich Beds near Chiselhurst a mass of the Blackheath Beds seems to be separated from the rest, in consequence of the northerly rise, about half a mile southward from the church, and just above Tong's Farm.

After quitting Chiselhurst and its surroundings the only section of note was in the railway-cutting through Bushey Leas Wood, which has been partly described before (fig. 15, p. 139), but the irregularity of the junction between the Oldhaven Beds and the London Clay may be better seen from the wood-cut below (fig. 44), which is from a sketch made just west of the bridge, on the left of the larger section.

Figure 44. Detail of Part of the Cutting on the Lewisham and Dartford (South Eastern) Railway through Bushey Leas Wood, near Bexley.



- |                   |                                      |
|-------------------|--------------------------------------|
|                   | a. Clay.                             |
|                   | b. Green marly bed.                  |
| London Clay.      | c. Brown sandy clay.                 |
|                   | d. Clayey pebble-bed (basement-bed). |
| Oldhaven          | e. Sandy shelly pebble-bed.          |
| Beds (4 of        | f. Laminated clay and sand.          |
| fig. 15, p. 139). | g. Sandy pebble-bed.                 |
|                   | h. White and yellow sand.            |

Westward of the road from Penhill Bridge the cutting showed brown, buff and grey sand, wet at the bottom, most likely from the shelly clays of the Woolwich Beds being at no great depth below; and, beyond the little hollow, patches of a pebble-bed (partly false-bedded) overlie the sand, and in this (on the northern side) is a small hollow of London Clay, with a clayey pebble-bed at the bottom. There may be more of the clay, but the amount of surface-wash makes it uncertain. At the western end the cutting is in pebbles and this surface-deposit.

#### *Up the Bexley and Eltham Valley.*

Up the side-valley, through which flows the small and (?) nameless stream that joins the Cray at Bexley, there is a continuous outcrop of the Blackheath Beds, below which indeed

the valley is not cut near Lamb-abbey, though westward, in the higher part of the valley, the underlying Woolwich Beds crop out, rising above the level of the Blackheath Beds on the south. The outcrop runs across the little watershed and reaches the southern side of the Mottingham valley, running northward along it to Eltham Green, and then, again turning eastward, rises to the higher level of Eltham, where the beds again revert to a slight northerly dip, and are soon covered by the London Clay.

The small cutting just eastward of Eltham Station showed at the western end a sandy pebble-bed, seemingly with clay (London Clay?) above; at the middle part sand with a few layers of clay; and at the eastern end a foot of a fossiliferous pebble-bed, partly hardened, over light-buff sand, in which latter there were a few shells at the extreme east.

In a small pit in a field a little southward from the station I saw a clayey pebble-bed (? basement-bed of London Clay) and, lying about, some small pieces of fossiliferous conglomerate.

In making the sewer along the high road at Eltham a great deal of hard shelly rock was found. Near the church there was much running sand, and at the eastern part of the village dry sand. This information was supplied by MR. HAWORTH, Surveyor to the Local Board, who also showed me a number of blocks of the hard bed, which is a calcareous sandstone with shells (*Calyptraea*, *Arca*, *Modiola*, *Ostrea*) and a few pebbles. In many blocks the shells had been dissolved out near the surface, leaving casts only.

Just outside the north-eastern corner of the park called "Eltham Place" on the Ordnance Map (1, S.W.), and therefore but a little south of the high road, a shallow pit (in ground now perhaps built over) showed the section below:—

Loamy pebbly soil, 3 feet or more, passing down into:—

Light-coloured (almost white) and brown sand, false-bedded, about 7 feet (not bottomed), most likely above the pebble-beds and therefore belonging to the Oldhaven Series.

Another pit on the same side of the high road and nearly opposite the gate of the park named "Eltham Park" on the Ordnance Map, dug for the foundations of a house, gave a like section, as follows:—

Loamy soil, about 2½ feet.

Clayey pebble-bed, about 2 feet (? basement-bed of London Clay).

Light-coloured Oldhaven Sand, as before.

The large pit, marked on the Ordnance Map, at the south-eastern corner of Eltham Park, gave the following section of this Series:—

Light-coloured and brown sand, roughly bedded, false-bedded, with inconstant layers (and at one part a continuous bed) of pebbles, more clayey at top, 10 feet at the thickest part.

Sandy pebble-bed, showing neither bedding nor false-bedding, as much as 12 feet dug into.

At the western edge of what was once West Wood, and just south of where the "O" of "Ox Leas Wood" is engraved on the old Ordnance Map (1, S.W.), a small pit showed a little loamy pebbly soil passing down into fine sand, the upper part with some clayey layers and therefore moist, the lower part dry and nearly white. Of this I saw about 8 feet, and was told that 5 feet more had been found. It must be the sand above the pebble-bed, as at Eltham.

A little eastward, in the former wood (now open land), there were two pits in the pebble-bed, above the new Farm House.

Along the boundary between a field and an orchard in the hollow just east of Upton, near New Bexley, the following succession of beds was shown:—

Blackheath Beds.	{ Pebble-bed, forming a hillock.
	{ Sand, cropping out for some way down.
	{ Pebble-bed, some feet thick.
Light-brown and grey sandy clay (Woolwich Beds).	

Close to the cottage in the hollow just north of Warren House, half a mile south of New Bexley, there was a small pit in this Series, showing about 6 feet of a bedded rather clayey pebble-bed, overlying very light-coloured sand, which was not bottomed.

*Up the Southern Side of the Valley of the Thames, from the Valley of the Cray.*

Between New Bexley, Belvidere, and East Wickham the out-crop is broad, forming a well-marked table-land; but westward of the last place it is comparatively narrow, though broadening at Blackheath, where the flat-making tendency of the pebble-beds is again well shown.

From Bexley, where it is at rather a low level, the boundary-line rises northward, and though as a rule not far from that of the Woolwich Beds, is not so parallel to it as is often the case, denudation having cut back the higher formation along some of the small valleys, and left small spurs of the lower one on the flanks of the hills.

From Belvidere westward along the valley of the Thames the boundary-line generally follows closely that of the Woolwich Beds, but is even more winding in character. There are plenty of sections, some already described (pp. 142, &c.), and the rest of no great interest, as a rule.

Through and on either side of Greenwich Park the boundary-line is particularly close to that of the Woolwich Beds, which are nearly cut off here, only the bottom-bed indeed remaining for the most part.

West of Blackheath the Blackheath Beds thin out, and on the other side of the valley of the Ravensbourne we see nothing of them, the London Clay there resting on the Woolwich Beds; unless it should turn out that the "striped sands," or fine alternations of sand and clay, belong to the upper rather than to the lower Series, a notion that would never have occurred to me had it not been for the thick mass of such sand and clay which I was led to map with the Oldhaven Beds near Bromley (see p. 221, &c.). The thinning out of the sandy pebble-bed seems to be shown however in the railway-cutting east of Lewisham Church (Fig. 20, p. 152).

There is no want of sections near New Bexley, but none call for remark here.

At Northumberland Heath a pit just south of the cross-roads gave the following section:—

Pebbly soil and irregular resorted pebble-bed; 4 feet to 8 feet; resting evenly on the bed below, except for a few small pipe-like hollows.

Cream-coloured and nearly white fine sharp sand; the bedding shown by thin clayey layers; 13 feet.

Pebbles (not shown, but into which I dug).

A like section occurred in another pit in the orchard a little to the south, where lancet-headed galleries have been driven in some yards from the face of the sand. Here the upper pebble-bed varied in thickness from nothing to 3 feet, and rested evenly on the sand, the uppermost 2 feet of which is darker, more clayey and with a thin broken layer of small flint-pebbles at the bottom.

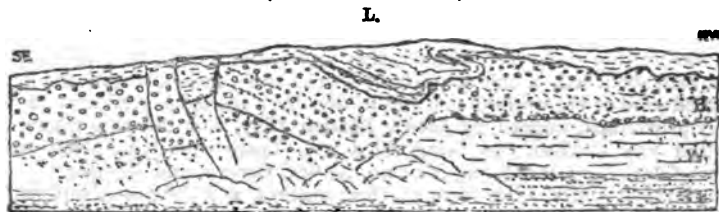
There must be 15 feet or more of the sand shown here, and it was said to have been worked deeper. There was also a small section of it lower down, close to the edge of the wood (southward).

At the southern side of the great pit, that reaches for half a mile westward of Erith Station, the junction with the Woolwich Beds is shown (see p. 142), and at the western end a peculiar section was seen, at top, in 1887, the beds being

- |                  |   |  |
|------------------|---|--|
| ? London Clay.   | { | 1. Brown sandy clay, apparently weathered London Clay, with              |
|                  |   | 2. Pebbles at the base. This has been dragged over on the northern side. |
| Blackheath Beds. | { | 3. Fine light-coloured sand.   |
|                  |   | 4. Sandy pebble-bed.   |

MR. GOODCHILD, who has noted this section,\* regards the downward drag of the thin pebble-bed as caused by glacial action. I am disposed however to look on it as caused rather by ordinary subaërial erosion down a slope; by the process indeed which carried away the London Clay from above. The top clayey bed, which occurs in a hollow, seems rather to be London Clay than Thames Valley Brickearth, as MR. GOODCHILD supposed. By the kindness of the Council of the Geologists' Association his section is reproduced (fig. 45). It must have been drawn when this side of the pit was clearer than at the time of my visit (with him). MR. SPURRELL has also given an illustration of this peculiar hollow.†

Figure 45. Section at the Western End of the Erith Sand-pit.  
(J. G. GOODCHILD.)



Scale 25 feet to an inch.

L. London Clay.

B. Blackheath Beds.

W. Woolwich Beds.

Th. Thanet Sand.

From the earth turned out from some rabbit-holes in the sandy pebble-beds in Abbey Wood I got the following fossils:—

Lamna teeth.

Cerithium.

Fusus.

Melania?

Melanopsis.

Neritina.

Cyrena cordata?

—— cuneiformis.

—— tellinella.

Nucula.

Ostrea.

Pectunculus (large).

Along the road down the hill S.S.E. of Abbey Wood Station there are again fossils in the pebble-beds, which however are unfossiliferous on the hill-top.

Along the narrow outcrop westward of East Wickham sections are plentiful, and chiefly show thick masses of pebbles in sand.

A little more than a quarter of a mile south of Plumstead Station, a pit, the bottom of which was at about the 100 feet contour-line, gave the following section, in 1887, showing an unexpected large mass of sand in this Series:—

Pebbles, up to 6 feet.

Pale buff sand, with some interrupted layers of pebbles and some thin layers of clay. 20 feet.

Sandy shell-bed, of the Woolwich Series, seen below northward and eastward.

\* *Proc. Geol. Assoc.*, vol. ix., No. 3, p. 158. (1885.)

† *Rep. W. Kent Nat. Hist. Soc.*, 1886. Fig. 1 of pl. ii.

In the road just eastward the sand was seen to dovetail into pebble-beds.

In a hole dug on the eastern side of Cage Lane, just above the fork, there was seen a mass of pebbles, to a depth of 10 or 12 feet (over Thanet Sand) which served as a good illustration of the difficulties that may occur in interpreting small sections of irregular gravelly deposits. It is known that the Blackheath Beds occasionally sweep or plunge down below the general level of their basement-plane, until they rest on the lower part of the Woolwich Beds (as is the case little more than half a mile S.E.) and even reach down to the Thanet Sand, though rarely. The mass in question at first led my friends MR. HOLMES and MR. GOODCHILD, who showed me the section, to think that such an occurrence might have happened here; but further examination led them to see that the pebbles had been deposited here through the denudation and downward wash from the hills above; for, not only is the deposit much below the level of the Blackheath Beds close by, but with the pebbles there are in places numbers of broken shells, derived from the sandy shell-bed of the Woolwich Series.

In some old pits at the western end of Plumstead Common the pebble-beds are in parts hardened into large masses of conglomerate.

At Elliott Hill, on the southern edge of Blackheath, sand has been found below the pebble-beds, and in a pit on the east, opposite Elliott Place, I saw sand at the northern end and pebbles at the southern, but from the section being much hidden could not see the relation between them.

Some deep cuttings, for drains, along the road about a quarter of a mile from the eastern end of Blackheath Park, gave the following section, in 1861:—

Made ground.

Brown loam, about 2 feet (P weathered London Clay).

Pebbles in clay (basement-bed of the London Clay) about a foot.

Light-coloured sand.

A like cutting along a small road, then private, on the eastern side of the main road about half a mile south from Blackheath Station, was in the light-coloured sand at the western end, and further from the main road was in the clayey pebble-bed, capped by brown London Clay, but the part where the junction was touched was being filled up. There were lying about many pieces of flaggy grit containing *Melania*, *Natica*, *Cyrena*, and *Modiola*.

In the tract under notice there are three outliers, as follows:—About half a mile N.N.W. of Crayford is a small patch; the same distance eastward of Northumberland Heath another; and in Abbey Wood another, just above Lesness Abbey.

#### *Faulted Masses.*

That part of the valley of the Thames just described is along a line of fault, the effect of which has been to throw down beds, of the same age as those that form the hill-top, to the bottom of the slope; though owing to their being soon hidden by the alluvium of the river, or wholly hidden by the River Gravel, little is to be seen of them.

(1.) The first of these faulted outcrops of the Blackheath Series seems to border the marsh from half a mile north-west of Erith Church to beyond Plumstead Church, a distance of three miles, but from the cause aforesaid is nowhere a quarter of a mile broad. The eastern part is however doubtful.

A well or tank, at a house in the south-western corner of the cross-roads just south of Abbey Wood Station, was sunk through 14 feet of a fossiliferous pebble-bed of the Blackheath Series; but in digging for foundations only a few feet to the north, at about the same level, brown loam was found.

Along the road about a third of a mile to the west the same fossiliferous pebble-bed occurs near the boundary of the alluvium; whilst a little to the south (and higher) there is light-coloured Thanet Sand.

These sections seem to be good proof of a fault with downthrow on the north, and further evidence is given by the wells at Crossness (see Well-sections) and by the great amount of pebbles on the surface in parts.

(2.) At Greenwich the same thing occurs, most likely from the westerly continuation of the same line of disturbance, but here the beds are wholly hidden by gravel, and the existence of the fault is shown by well-sections only (see *post*), which however are quite enough to prove that the beds, of the same age as those high up in the park, are thrown down to a much lower level in the town.

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Before crossing the Thames, into Essex, some occurrences in the bed of the river may be noticed.

MR. F. W. RUDLER showed me a specimen of sandstone with shells and pebbles which had been dredged up, by the Thames Conservancy, opposite Limehouse Reach, at a depth of  $3\frac{1}{2}$  feet below Ordnance Datum; but whether it came from a loose block, or from a bed in place, is doubtful: the depth, above low-water-mark, is suggestive of the former.

Some masses of very fossiliferous conglomerate, said to have been found in sinking for the foundations of the piers of Westminster Bridge, were sent to the Jermyn Street Museum, and many species were determined therefrom by MR. ETHERIDGE. In this stone the black flint pebbles were few, the matrix being the usual calcareous sandstone. Judging from well-sections in the neighbourhood one would not expect this bed to be found except at a great depth, and here again therefore it is a question whether the stones were in place, or whether they may not have been brought there.

#### *South Essex.*

This Series seems to stretch across the Thames into Essex, and perhaps the uprise of the Lower London Tertiaries at Stratford may belong to it, at least in part (see p. 168).

It seems to occur also under the alluvium of the Isle of Dogs at Millwall.

In the neighbourhood of Orsett, and for nearly three miles eastward therefrom, MR. BRISTOW observed beds which belong to this Series, and the following remarks are from his notes. After their publication, in vol. iv. of the Geological Survey Memoirs, I examined the ground, at his request, in 1872, and drew the boundary-line, as well as the very scanty evidence would allow.

"At the Union House Orsett a well was sunk through a bed of pebbles, from 6 inches to 2 feet thick, over 45 feet of sand, and the water came from beneath the pebbles."

"This pebble-bed may be well seen about here, and eastward through Cherry Garden, Saffron Garden, and Pearls. Between Orsett and Dalton's Shaw it forms the surface of the ground over a considerable tract, and may be seen overlying yellow and bright red sand in the little copse south of a row of houses at the latter place."

"At Hassenbrooke the well on the western side of the farm-buildings is in pale brownish quartz-sand. The garden between the house and Jeffries is upon the pebble-bed, and above the sand of the well; a layer of shells was under the pebbles. The farmer here had some very productive strawberry-beds, and the fruit, well-known for its good quality, fetched a high price. I was told that the produce of 12 acres fetched 100*l.* a week in Covent Garden Market, a price much above what the neighbouring growers could get. The explanation of this difference in quality is I believe that the sandy pebble-bed upon which these strawberries are grown makes a soil especially favourable for their cultivation, and that good gardening has little to do with the matter."



"At Moore's Place the house is on sand. The well in the old farmyard on the north-east is also in sand. In the meadow south of the railway a thickness of about 4 feet of black pebble-gravel was seen, over sand with a layer of shells."

Perhaps the upper part of the sand in the railway-cutting south of Stanford Station may belong to this Series (see p. 170).

*Kent, between the Thames and the Medway.*

*Main Mass.*

The Oldhaven Beds (consisting almost wholly of sand) rise from the marshes of the Thames north of High Halstow, and their narrow outcrop follows that of the Woolwich Beds for some three miles, to Oakley, near Higham, where it turns southward, not stretching over the spur of the latter at Higham. The boundary-line however again approaches that of the Woolwich Beds at Littlechurch, and then follows it eastward to the Medway, near Hoo, beyond our district.

At High Halstow Kiln, west of the church, the section was as follows:—

London Clay.	{	Brown clay with selenite, septaria in one layer, showing a slight dip a little east of south; 15 feet or more in the highest pit, near the hill-top. Grey bedded clay (middle pit).
--------------	---	--

The beds below were shown in a sand-pit lower down, and close to the kiln.

Oldhaven Beds.	{	Light-buff sand, about 6½ feet; with a layer of casts of <i>Cypriæ</i> nearly 2 feet down, and at one part another layer a foot lower. Black flint-pebbles in sand, about 6 inches, with at one part a 3-inch layer of shells at top (for the fossils of which see p. 236).
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Fine sharp light-coloured sand of the Woolwich Beds.

The lower beds were not laid open, but were found by digging down two or three feet below the bottom of the pit.

A little way westward, along the more northerly of the two roads that fork here, a bed of shells (with here and there a pebble) in the Oldhaven Sand crops out; and it is remarkable that the five species found in it are all estuarine, whilst those at the kiln close by are marine.

The railway-cutting east of Cooling Court, laid open the whole of this division of the Lower London Tertiaries, there only 10 feet thick (see p. 171).

The next section seen was at Mortimers,\* nearly two miles south of Cliffe, where is a small road-cutting. A few yards south from the top of the rise a thin bed of small pebbles comes on, with a little fine, sharp, light-coloured sand beneath. This shows the bottom of the Oldhaven Beds; further south the pebbles seem to be replaced by light-coloured sand full of estuarine shells, a list of which is given at pp. 236, 237.

From hence little is to be seen until we reach the great pits at Upnor, beyond our district (in Sheet 6).

*Outliers.*

At the top of Windmill Hill, Gravesend, there are two very small patches of the sandy pebble-beds (see p. 174).

About three miles east of that town is a mass capped by London Clay and in great part hidden by alluvium and gravel. The outcrop is narrow, as in the main mass on the east.

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\* Wrongly called "Bluegate" on the old Ordnance one-inch Map (Sheet 1, S.E.). (Altered on the Geological Survey plate.)

The shallow cutting on the North Kent Railway, about a mile and a half westward of Higham Station, is in gravel with coarse sand; but a ditch on the northern side, carried some 10 feet below the level of the rails, showed the beds beneath (at the central part of the cutting), and the section was as follows:—

London Clay. { Bluish-grey laminated clay.  
 Grey and brown loam (basement-bed) with a ferruginous  
 bed at bottom.  
 Oldhaven Beds? Buff clayey sand.

In the gravel-pit at the eastern end of this cutting, and on the northern side of the line, there is, below gravel, brown ferruginous sand, often rather hard, with large, flat, round-edged slabs of sandstone, which contains a few fossils (*Panopæa*, *Pectunculus decussatus*, and a small spiral univalve), about 6 inches thick, and which split along the planes of bedding. One could not dig below this bed, which most likely belongs to the Oldhaven Series, on account of the water.

The sides of the next cutting, about a mile westward of Higham Station, were almost wholly overgrown when I was there (in 1862), but the Woolwich shell-beds were to be seen near the eastern end (see p. 172). A little west of them there was shown on the northern side a bed of calcareous sandstone, splitting along the planes of bedding, in parts very full of shells, sometimes with pebbles, often with green grains, and about 15 inches thick. This most likely belongs to the Oldhaven Series, and a list of the fossils from it has therefore been given at pp. 236, 237. Towards the western end brown London Clay comes on.

The eastern end of the large mound or island in the alluvium, on the northern side of the canal, seems to consist of sandy pebble-gravel.

#### FOSSILS.

PROF. PRESTWICH, as before noticed (p. 101), includes our fossiliferous pebble-beds with the Woolwich Beds; but as, in mapping, it is almost impossible to separate these from unfossiliferous pebble-beds, which he is disposed rather to include with the Blackheath Beds, their fossils are here listed apart from those of the estuarine Woolwich Series, with which they have a certain kinship. On the other hand the marine species are more allied to those of the London Clay above. Under the circumstances it seems best to have a separate list, which is practically the same as leaving the question an open one, as far as the palæontology of the beds is concerned.

The localities are shown by numbers in the list, as follow:—

1. *Westminster Bridge*.—Determined by MR. R. ETHERIDGE from specimens (given to the Geological Survey) found in sinking for the foundations of the piers.
2. *Dulwich*.—Brockwell Hall Brickyard. Determined by MR. ETHERIDGE from specimens collected by MR. R. GIBBS; some found and determined by myself.
3. *Beckenham*.—Railway-cutting. From my own collecting and from specimens collected by MR. GIBBS and determined by MR. ETHERIDGE.
4. *Croydon*.—From specimens in the collection of DR. A. CARPENTER of Croydon, found in making the Norbury sewer, with additions from Park Hill, by H. M. KLAASSEN, *Proc. Geol. Assoc.*, vol. viii., no. 4, pp. 243, 244.
5. *Sundridge*.—Rock-pit and railway-tunnel. PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. x. pp. 100, 101. C. EVANS, *Geologist*, vol. vii. p. 35; from my own collecting; and from specimens collected by MR. GIBBS and determined by MR. ETHERIDGE.

6. *Charlton*.—PROF. PRESTWICH, *Quart. Journ. Geol. Soc.* vol. x., pp. 102, 103.
7. *Near Higham*.—From the Geological Survey Collection, chiefly determined by MR. ETHERIDGE.
8. *Hundred of Hoo*.—From specimens got by PROF. T. MC. K. HUGHES and by myself, partly named by MR. ETHERIDGE. H = *Halstow* Brickyard. M = *Mortimers*.

## FISH.

Lamna, teeth, vertebrae.	-	-	-	-	-	4	5	6	7
Otodus, teeth	-	-	-	-	-	-	5		
Bones, scales	-	-	-	-	-	-	5		

## MOLLUSCA.

## Gasteropoda.

Actæon (= Tornatella)	-	-	-	-	-	-	5		
Aporthais Sowerbyi, Mant.	-	-	-	-	-	3	-	-	7 8 H
Auricula pygmaea, Mor.	-	-	-	-	-	-	5	6	
Buccinum ?	-	-	-	-	-	3	-	-	7
Calyptrea trochiformis, Lam.	-	-	1	2	3	4	5	6	
Cerithium Bowerbankii, Mor.	-	-	-	-	-	-	5	6	
" funatum, Mant. (including C. variabile, Desh.)	-	-	1	2	3	-	5	6	7
" Lunnii, Mor.	-	-	-	-	-	-	4	5	6
" sp.	-	-	-	-	-	-	4	-	- 8 M
Dentalium (or Ditrupa)	-	-	-	-	-	-	4	-	
Fusus gradatus, Sby.	-	-	-	-	-	-	5	6	
" latus, Sby.	-	-	-	-	-	-	5	6	
" planicostatus, Mell. ?	-	-	-	-	-	-	-	6	
" subnodosus, Mor.	-	-	-	-	-	-	5	-	
" sp.	-	-	-	2	3	-	-	-	7 8 H
Hydrobia Parkinsoni, Mor.	-	-	-	-	-	-	5	6	
" Websteri, Mor.	-	-	-	-	-	-	-	6	
Melania inquinata, Desf.	-	-	1	2	3	4	5	6	7 8 M
Melanopsis ancillaroides, Desh. ?	-	-	-	-	-	-	5	6	
" buccinoides, Fer.	-	-	-	-	-	-	5	6	
" subfusiformis ?	-	-	-	-	-	-	-	6	
" sp.	-	-	-	-	3	4	-	-	- 8 M
Murex foliaceus, Mell. ?	-	-	-	-	-	-	-	6	
" sp.	-	-	-	-	-	-	5	-	
Natica labellata, Lam. (= N. glaucinoides, Sby.)	-	-	-	-	-	-	5	6	- 8 H
" patula Lam. (not Sby.)	-	-	-	-	-	-	-	-	7
" (= Ampullaria) subdepressa, Mor.	-	-	-	-	-	-	5	-	
" sp.	-	-	1	2	3	-	-	-	
Neritina consobrina, Fer.	-	-	-	-	-	-	-	6	
" globulus, Desf.	-	-	-	-	-	-	5	6	
" vicina, Mell.	-	-	-	-	-	-	-	6	
" sp. ?	-	-	-	-	3	4	-	-	- 8 M
Odostomia	-	-	-	-	-	-	5	-	
Paludina lenta, Brand., var. β. Mor.	-	1	-	-	-	-	-	-	
Patella	-	-	-	-	-	-	5	-	
Pitharella Rickmanni, Edw.	-	-	-	-	-	-	5	-	
Planorbis hemistoma, Sby.	-	-	-	-	-	-	5	6	
Pseudoliva fissurata, Desh.	-	-	-	-	-	-	-	6	
" semicostata, Desh.	-	-	-	-	-	-	5	-	
Ringicula turgida, Charlesworth	-	-	-	-	-	-	5	-	
Rostellaria ?	-	-	-	-	-	4	-	-	7
Scalaria	-	-	-	-	-	-	5	-	
Turritella	-	-	-	-	3?	-	5	-	7
Voluta ?	-	-	-	-	-	-	-	-	7

*Lamellibranchiata.*

<i>Arca depressa</i> , Sby. -	-	-	-	-	-	-	-	6	
" <i>laekeniana</i> , ? <i>Le Hon</i> . -	-	-	-	-	-	-	-	5	
<i>Avicula</i> -	-	-	-	-	-	-	-	5	
<i>Cardium</i> <i>Laytoni</i> , Mor. -	-	-	-	-	-	-	-	5	7 8 H
" <i>plumsteadensis</i> , Sby. -	-	-	-	-	-	-	-	5	6 7 8 H?
" <i>semigranulatum</i> , Sby. -	-	-	-	-	-	-	-	-	7
" sp. -	-	-	1	2	-	4	-	-	-
<i>Corbula</i> <i>Arnouldi</i> , Nyst. -	-	-	-	-	-	-	-	5	
" <i>regulbiensis</i> , Mor. -	-	-	-	-	-	-	-	5	- 8 H
" sp. -	-	-	-	-	-	-	-	-	7
<i>Cyprina</i> <i>Morrisii</i> , Sby. -	-	-	-	-	-	-	-	-	7 8 H
<i>Cyrena cordata</i> , Mor. -	-	-	-	-	3	4	5	6	
" <i>cuneiformis</i> , Fer. -	-	-	1	2	3	4	5	6	7 8 M
" <i>intermedia</i> , Moll. -	-	-	-	-	-	-	5	6	
" <i>tellinella</i> , Fer. -	-	-	-	-	-	-	5	6	- 8 M
" Psp. (shape of <i>C. cordata</i> but banded like <i>C. dulwichensis</i> ) -	-	-	-	-	3	-	-	-	
<i>Cytherea obliqua</i> , Desh. -	-	-	-	-	-	-	-	-	7
" <i>orbicularis</i> , Edw. (taken for <i>C. bellovacina</i> , Desh.) -	-	-	-	-	-	-	-	-	7
" sp. -	-	-	-	-	-	-	-	5	
<i>Glycimeris</i> -	-	-	-	-	-	-	-	5	- 7
<i>Lucina</i> -	-	-	-	-	-	-	-	5	
<i>Modiola dorsata</i> , Mor. -	-	-	-	-	-	-	-	5	
" <i>Mitchelli</i> , Mor. -	-	-	-	2?	-	-	5	6	
" sp. -	-	-	-	-	-	4	-	-	
<i>Nucula fragilis</i> , Desh. -	-	-	-	-	-	-	5	6	
" <i>gracilentia</i> , Wood (also found at Bickley) -	-	-	-	-	-	-	5	-	
" sp. -	-	-	-	-	-	-	-	-	- 8 H
<i>Ostrea bellovacina</i> Lam. (including <i>O. edulina</i> , Sby.) -	-	-	1	-	3	4	5	6	
" <i>flabellula</i> , Lam. -	-	-	-	-	-	-	5	-	
" <i>tenera</i> , Sby. -	-	-	-	-	-	4	5	6	
" sp. -	-	-	-	2	-	-	-	-	7 8 M
<i>Panopæa intermedia</i> , Sby. -	-	-	-	-	-	4	-	-	7
<i>Pectunculus brevisrostris</i> , Sby. -	-	-	-	-	-	-	5	6?	
" <i>plumsteadensis</i> , Sby. -	-	-	-	-	-	4	5	-	7
" <i>terebratularis</i> , Lam. -	-	-	-	-	-	-	5	6	7
" sp. -	-	-	-	-	-	4	-	-	- 8 H
<i>Pholas</i> -	-	-	1	-	-	4	5	6	
<i>Tellina</i> -	-	-	-	-	-	-	5	-	
<i>Teredina personata</i> , Desh. -	-	-	-	-	-	-	-	6	
<i>Teredo antenata</i> , Sby. -	-	-	-	-	-	-	5?	6	
<i>Unio</i> ? -	-	-	1	-	-	-	-	-	

*Polyzoa.*

<i>Cribrilina radiata</i> , Moll. -	-	-	-	-	-	4	
<i>Flustra</i> -	-	-	-	-	-	-	5
<i>Polyzoon</i> , undetermined -	-	-	-	-	-	-	6

CRUSTACEA, CIRRIPIDIA, and  
ANNELIDA.

<i>Cancer</i> ? -	-	-	-	-	-	-	5	6
<i>Entomostracan</i> ( <i>Cythere</i> ) -	-	-	-	-	-	-	5	
<i>Belanus</i> ? -	-	-	-	-	-	-	-	6
<i>Serpula</i> -	-	-	-	-	-	-	5	

## PLANTS.

Seed-vessels -	-	-	-	-	-	-	-	6
Wood -	-	-	-	-	-	4	5	
Plant-remains -	-	-	-	-	-	3	-	5

The plant-remains from Widmore Kiln, Bromley, are noticed on p. 213.

## CHAPTER 15. LONDON CLAY.

## GENERAL REMARKS.

This formation had its name from WILLIAM SMITH, since whose time of course much has been done to clear up its relations to the beds above and below, chiefly however in the Hampshire Basin, where the Barton Clay, which is at a higher geological horizon, being above the Bracklesham Beds and the (Lower) Bagshot Sand, was formerly classed with it. The definite separation of the true London Clay, from the other clays that had been mistaken for it, was worked out by PROF. PRESTWICH, but not before even he had been involved in the mistake. To the same geologist we owe also the recognition of the "basement-bed" that nearly everywhere marks the beginning of the London Clay; and, as he has described the lithological structure of the formation, one cannot do better than quote from his papers in the following remarks.

*Structure.*

"The main body of the London Clay presents throughout its whole range a uniformity of mineral structure so well marked and distinct, that either by this character alone, or else by its organic remains, when present, it can almost always be readily recognized. . . . In the Tertiary district westward of London the London Clay consists of tenacious brown and bluish-grey clays with layers of septaria [large irregular-shaped nodular masses of clayey limestone, with divisions, or *septa*, of calcspar or of arragonite]. . . . Immediately at its base the London Clay commonly contains a greater or lesser admixture of green and yellow sands generally mixed with rounded flint-pebbles, and not unfrequently cemented by carbonate of lime into semi-concretionary tabular masses. These mixed beds however never exceed a few feet in thickness, and pass upwards rapidly into the great mass of the London Clay."\* To this part of the formation MR. PRESTWICH has given the name of the "basement-bed." It often contains many fossils, and a list of those found in it in our district is given at pp. 263-265. In the western part of the London Basin this bed often rests on an uneven surface of the Reading Series, showing that the latter had been slightly worn before its deposition.

The brown colour of the London Clay at and near the surface is merely a colour of decomposition; the protosalt of iron that gives the bluish tint peroxidating by exposure to atmospheric action. It is a question too whether septaria are not in some measure owing to infiltration.

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\* *Quart. Journ. Geol. Soc.*, vol. vi. pp. 253, 254.

In their paper on "Microzoa from the London Clay . . . . . in the Drainage Works, Piccadilly."\* MESSRS. C. D. SHERBORN and F. CHAPMAN quote a note from PROF. PRESTWICH, who says "It is probable that the brown clay belongs to a slightly higher bed, and it may be that the colour is due to the bed being slightly more porous, and to the percolation of the surface waters having oxidized the iron in it, producing the brown colour." Whilst agreeing with the cause of the brown colour being here as elsewhere, caused by oxidation, I doubt whether it need have anything to do with bedding; for this discoloration takes place along irregular surfaces that cut across various beds. The authors however (after noticing a difference in the abundance of some Foraminifera in the two clays) remark "that the residuum, after washing, of the brown clay was mainly small crystals of selenite, a little coarse subangular sand, and microzoa, the whole residuum being  $2\frac{1}{2}$  per cent. by weight of the amount washed . . . Of the black clay . . . the residuum,  $1\frac{1}{2}$  per cent. by weight of the sample taken, consisted of fine sand, mica, a little carbonaceous matter, and microzoa. No selenite was found." These differences are such as would result from the action of infiltrating water.

PROF. HENSLOW has recorded the fact that nodules from the London Clay near Euston Square contained 50 or 60 per cent. of phosphate of lime.†

The upper beds, like the basement-bed, are more sandy than the larger mass of the formation, "and near the top usually mixed with light-coloured sands in sufficient quantity to form a good brick-clay without any further addition of sand."‡ Whilst however the basement-bed is often shown in sections, it being very constant, the topmost part of the formation is of comparatively rare occurrence, owing to denudation, being seldom found at any great distance from the overlying Bagshot Beds.

#### *Character of the Fossils, and the Conditions they point to.*

The fossils of the London Clay, which are plentiful in some districts, but rare in others, are of kinds which must have lived in a fairly warm climate. PROF. PRESTWICH says of the fauna of the London Clay, that "taken altogether, it rather indicates a moderate than a tropical climate, and yet the flora is, as far as we can judge, certainly tropical in its affinities."§ PROF. T. R. JONES tells me that "the indication of sea-depth for the London Clay afforded by the *Foraminifera* is that the water was about 100 fathoms deep."

PROF. PRESTWICH again says that the "lithological character denotes a tranquil and uniform deposit during some length of time; and as the evidence of fossils proves that the condition of animal life was similar at the end to that which existed at the commencement of this period, it follows that there must have been throughout its duration a quiet and gradual subsidence of the bed of the sea."|| "The increasing depth caused by the subsidence appears to have been constantly neutralized by an accumulation of sediment, equal, or nearly so, to the amount of depression. By

\* *Journ. R. Mic. Soc.*, ser. ii., vol. vi. (1836.)

† *Rep. Brit. Assoc. for 1845, Sections*, p. 51.

‡ *Prestwich, Quart. Journ. Geol. Soc.*, vol. iii. p. 364.

§ *Quart. Journ. Geol. Soc.*, vol. x. p. 448.

|| *Ibid.*, vol. ii. p. 237.

the joint and counteracting effects of these two causes a nearly uniform and moderate depth was maintained throughout the seas then covering these districts, enabling the *Panopæa*, *Pholadomya*, *Pinna*, and other shallow-water genera, to exist all through this geological period, to the exclusion of the more varied fauna which greater changes of depth would have produced. But we have indications, as we proceed further eastward in the London district to Highgate and Sheppey, of a departure during part of this period from these uniform zoological conditions; for . . . we here find various species of *Cephalopoda*, *Echinodermata*, some *Brachiopoda*, and of a generally deeper sea testacea. . . . From the operation of more numerous zones of depth, adapted to the existence of more numerous classes of Testacea, results probably the more diversified and abundant fauna of Hampstead, Highgate, and Sheppey.”\*

Although the fossils are alike throughout this formation, yet the same species are not found equally from top to bottom, and by a very careful comparison of the fossils from different places PROF. PRESTWICH has inferred the existence of four zones in this thick mass of clay. He says, “The organic remains of the London Clay are distributed in groups marking particular zones. . . . Confining ourselves to the London district, it would appear that, although a great proportion of the fossils range at intervals vertically throughout the London Clay, yet their development is very different in different zones, being abundant in some and scarce in others, whilst each zone is further marked by a few characteristic species, thus forming distinct, although nearly related groups. . . . It must not, however, be supposed that the fossils are dispersed either vertically or horizontally with any uniformity as to numbers. . . . These zones are necessarily artificial, as no actual division exists, and the organic remains and mineral characters are continuous; but they serve to mark the distinct conditions of the fauna and flora at particular periods, and show the prevalence generally of like forms on the same levels; they are not, however, to be taken by any means as constant, but merely as local centres for convenient reference and grouping.”† Before the above was written, MR. WETTERELL had noticed the probable division of the London Clay (near London) into three zones.‡

The reptilian fauna and the rich fruit-flora of Sheppey are not represented in the neighbourhood of London.

#### *Range and Thickness.*

This formation occurs through the greater part of our district, and comes to the surface over a large area, being moreover but thinly capped by Drift over extensive tracts. In thickness it comes

\* *Quart. Journ. Geol. Soc.*, vol. iii. pp. 394, 375.

† *Ibid.*, vol. x. pp. 408, 409.

‡ *Phil. Mag.*, ser. 3, vol. ix. p. 462. (1836.)

second to the Chalk, being far ahead of any other of the local formations. On the west, near Windsor, the full thickness may be less than 400 feet; but the clay thickens slowly eastward, until near London it is over 400 feet thick, and on the east probably reaches to about 480 feet. Of course in all cases the full thickness must be measured, or estimated, from the bottom of the Bagshot Beds downward.

#### SOUTHERN BORDER OF THE LONDON BASIN.

##### *Between the Mole and the Wandle.*

From the northern part of Leatherhead the boundary-line runs north-eastward to Ewell, and thence a little north of east to Croydon, roughly parallel to that of the Reading Beds, but in a somewhat less irregular course. Not having either seen a single section of the basement-bed or found any account of one, it can easily be understood that the boundary-line is doubtful in many places. As the broad tract of this formation, northward to the Thames, is chiefly free from Drift, its clayey nature is most marked. The flat tops of the high ground of Richmond Park and of Wimbledon Common and Putney Heath are caused by spreads of gravel.

At Leatherhead there are two brickyards in the London Clay, between the village and the railway-station.

The next sections are at Epsom; at the brickyard on the eastern side of the common, in the railway-cutting just to the south, and where the same line crosses the road up to Clay Hill.

The Clay is again shown in the railway-cutting by Ewell Court, and on the turnpike-road at the north-western corner of Nonesuch Park, by the 13th milestone.

There are two brickyards on the north of Sutton, about half a mile from the boundary-line. MR. H. H. FRENCH tells me that he found, in 1887, at one of the Sutton brickyards, "great quantities of wood, bored throughout by molluscs. Some of the branches, or trunks, were from 7 to 10 feet long, and from an inch to 6 inches in diameter."

At Carshalton Gas-works stiff blue clay was found. Eastward of this the junction with the Reading Beds is hidden by the gravel of the Wandle.

Besides the sections above-noticed, which are near the boundary, there are others farther from it, both on high and on low ground.

At Norbiton Pottery, near the top of Kingston Hill, there is a good section, that seems to show a passage of the London Clay into the overlying Bagshot Sand. At the top there is brown sandy clay, not unlike that of the basement-bed in the neighbourhood of Reading, &c., many feet thick, and beneath this is dark bluish-grey rather sandy clay. There are septaria at or near the junction, which is fairly marked, and for the most part even, and also in the lower clay. I was told that lower down the clay was not sandy. The dark grey clay yields many fossils, and so do many of the septaria in it. The following is a list of those found here by MR. RICHARD GIBBS (then fossil-collector of the Survey) and by myself:—*Nautilus*, *Phorus extensus*, *Cyprina*, *Modiola elegans*, *Mytilus*, *Ostrea*, *Pecten corneus*, *Pectunculus decussatus*, *Solen affinis*.

A thin patch of the Bagshot Sand seems to come on a little higher up the hill.

A mile rather S. of W. from Wimbledon Railway Station, by a new road high up on the southern flank of the Ridgway, there was (in 1859, 60) a small



section showing about 8 feet of grey clay, finely and evenly laminated by partings of sand with a few small pieces of ironstone. This must belong to the topmost part of the London Clay, and clearly shows a passage upwards into the Bagshot Sand.

A like bed was found, below the gravel, in digging for the foundations for some houses on the top of the hill, less than half a mile N.W. of the railway-station.

*Between the Wandle and the Ravensbourne.*

At Croydon the London Clay seems to have been cut back northward in a bay-like form, but the boundary-line is in great part hidden by the thick mass of gravel here. The sections at Selhurst however show that there must be a slight upheaval, as else the beds below would not have been laid bare.

From Addiscombe the London Clay runs north-eastward, being separated from the Chalk by a broad outcrop of Lower London Tertiaries, and its boundary-line having a much more irregular course than before, with spurs jutting out over the broad outcrop of the Blackheath Beds; there are too outliers.

At the brickyard near the Croydon and Wimbledon Railway, about a mile and a quarter N.W. of Croydon Church, there are two beds of septaria in the clay. In both the nodules are close together; the lower one had not been sunk through when I saw the section, but formed a natural floor. Many of the septarian blocks, some of which were large, had been exposed for a long time, and had weathered into a circular form.

In a field on the northern side of the by-road nearly three quarters of a mile to the west of West Croydon Railway Station, a small shallow pit was seen, in 1859, in brown sandy clay, probably the lowest part of the London Clay. In the cutting at the station the clay is shown beneath the gravel.

At West Croydon Station I saw our first section of the basement-bed, and at Thornton Heath Station the junction with Oldhaven sand was again seen, as also at the Selhurst brickyard (see pp. 216, 217).

The cuttings on the Addiscombe Railway, from Woodside northward for more than two miles, are in London Clay, in great part with a thin capping of pebble-gravel. In that just south of the London Chatham and Dover Railway the gravel might easily be taken for the pebble-bed of the Blackheath Series (being sandy, bedded, and with layers of sand), but that the London Clay occurs below it. The clay is here blackish and for the most part stiff, though sometimes sandy. In the cutting between the London Chatham and Dover and the Mid Kent Railways the bottom of the London Clay was shown, with pebbles and green grains, underlain by about 6 inches of grey sandy clay, below which is a bed of very small pebbles in sand (a pea-gravel). The clay rests somewhat irregularly on the pebble-bed and ends off on the southern side of the brook.

In a well at Ham Farm about 20 feet of clay were sunk through; the upper part yellowish, the lower blue and shaly (bottom of London Clay). And in another well, at the keeper's cottage, not a quarter of a mile N., a thickness of 18 feet of a like clay was found above a loamy gravel, consisting of pebbles not much larger than peas (basement-bed?).

At a brickyard near Kent House, and about a mile N.W. of Beckenham, there was London Clay with septaria, and lower down a brown loam (? drift, or basement-bed). At another brickyard more than a mile S.W. the like was shown.

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Turning now to the higher ground of the Norwood Range, we have sections of higher beds.

A new cutting on the western side of the road running southward from the Gipsy Hill Railway Station, and close to the top of the hill, showed (in 1865) some 20 feet of evenly laminated buff and pale grey loam, clay and sand, belonging to the top part of the London Clay; and there were smaller sections of the same close by.

At Upper Norwood there was, in 1870, a good section of the top part of this formation on the road to Dulwich (and not far from the Crystal Palace), the beds being as follows:—

Clayey and gravelly soil.

Buff, finely bedded loam, sand and clay, the bottom part more clayey; about 25 feet.

The cutting on the South London Railway at the northern front of the Crystal Palace, from the station to the tunnel-mouth, gave another like section, consisting of alternations of clay, loam and clayey sand, flat and evenly bedded, brown (except the top 6 feet or so, which is mottled bluish-grey clay), with radiating selenite-crystals and many impressions of the same, and here and there with a little laminated green sand.

MR. CALEB EVANS made a large collection of fossils from the tunnel on the London Chatham and Dover Railway through Sydenham Hill.

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At the end of his paper on the section at the London Gas Light Company's premises just east of Battersea Park (from which long extracts will be found further on), MR. COOMBS notices the London Clay that everywhere formed the base of the excavation. Though this formation was cut into to a depth of but a few feet, yet a good many species of fossils were found, "by far the most abundant" being *Pentacrinus sub-basaltiformis*. "Septaria were abundant . . . many of which contained drift-wood, bored by the *Teredo* . . . selenite however was very scarce."

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The nine outliers that have been mapped now claim attention. The chief of them reach to near the main mass.

At Croydon an outlier, with a rather vague boundary, reaches southward from the Addiscombe Road, a little east of the railway-station, for about a third of a mile.

In a garden just eastward of the house at Park Hill I saw (in 1870) a hole, dug for a greenhouse-furnace, 12 feet deep in London Clay, which was then not bottomed. This seems to be a separate patch (far too small to be shown on the one-inch map) as it is surrounded on all sides, as far as I could learn, by pebbles and sand.

At Shirley, east of Croydon, is a rather larger mass, but without any section; indeed I failed to notice it when first in that neighbourhood, and consequently it is not shown on the earlier issues of the Map (Sheet 6).

Just west of Cold Harbor, north of Addington, there is a very small outlier; another touching the eastern side of the same place, where a well was sunk through about 3 feet of yellow clay and 11 feet of sand and gravel (Blackheath Beds); and a third, still smaller, about a quarter of a mile to the north-east.

A larger outlier stretches for nearly a mile and a half from Monks Orchard northward, through Eden nearly to Beckenham: perhaps indeed it may join the main mass between that place and Elm-end Green.

Near and east of this is a small and rather doubtful patch, and another occurs about half a mile east of Beckenham Church.

*Pickhurst Green*.—A thick mass stretches from this place northward, along the hill forming the left bank of the Ravensbourne, for more than 2½ miles, but is nowhere a mile broad.

MR. R. B. LATTER told me that, in sinking a well at Pickhurst Green, 40 feet of London Clay were passed through, without getting to the bottom of that formation, of which there are plenty of signs, but no good section, excepting in the railway-cutting on the north (Fig. 37, p. 219).

*Between the Ravensbourne and the Cray.*

North of Bromley the boundary-line runs eastward from the Ravensbourne, but soon turns northward, along the tributary Mottingham valley. Then turning eastward again, near Eltham it passes along the southern foot of Shooter's Hill, with two spurs, and skirts the eastern and northern bases of the same hill, finally sinking again to the bottom of the aforesaid tributary-valley above Lee, whence it is hidden, for some way, by Valley Gravel.

The mass of Shooter's Hill might indeed, at first sight, be thought to be an outlier, separated along the low ground between Lee and Eltham, where there is a thin spread of gravel; but according to MR. HAWORTH, Surveyor to the Local Board of Eltham, the sewer along the high road, which is over 12 feet deep, is in blue clay.

The cuttings on the Lewisham and Tunbridge Railway near Grove Park and Burntash are in London Clay, in parts with a thin irregular capping of drifted loam and gravel, not of extent enough to be mapped. The like occur in the cutting on the Dartford loop-line east of Burntash Lane, in the deeper part of which a septarian layer in the London Clay is sometimes continuous, with a dip of  $2^{\circ}$  or  $3^{\circ}$  along the line westward.

The tile-kiln at the southern edge of Plumstead Common is on the edge of the London Clay. At the northern part of the pit there were shown at the bottom (in 1861) about a foot of grey and somewhat greenish loam and about 6 inches of a clayey pebble-bed, which two represent the basement-bed. I was told that sharks' teeth and casts of shells were found on the top of the pebbles, and that below them the sandy Blackheath pebble-bed occurred. The dip is about  $4^{\circ}$  or  $5^{\circ}$  southward.

At a brickyard about half a mile to the west (by Orchard Place) there was a little loam at the bottom of the London Clay; and in the cutting of a new road (1870), running north and south, about a quarter of a mile north-east of the Royal Military Academy, the junction with the pebble-beds of the Blackheath Series was shown; the bottom part of the clay was loamy.

In some borings on Kidbrooke Common, to try the ground for the new hospital, a thickness of from 30 to 50 feet of clay was found.

At Lee Green Farm, on the southern side of the high road, just east of Burntash Lane, 40 feet of "blue marl" [London Clay] were passed through in making a well.

I was told that in a well sunk at Hither Green 20 feet of clay were found, gravelly at the top and also at the bottom, from which one may infer that the basement-bed was touched. On the west the junction with the beds below was shown in the railway-cutting (see Fig. 20, p. 152).\*

In this tract there are many outliers of London Clay scattered over the plain of the Blackheath Beds; but most are small, and only two (northward and southward of Chiselhurst) can be called large.

About half a mile N. and N.E. of Hayes there seem to be two small patches of clay.

*Shooting Common.*—The high road from Mason's Hill, Bromley, to Bromley Common is along an outlier about a mile and a half long and half a mile broad. The clay has been dug in Mr. Coles Child's Park, just south of the

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\* In vol. iv. of the Geological Survey Memoirs this paragraph and the one before it got mixed, to the detriment of the sense.

railway, the junction with the beds below is well shown at the brickyard a little eastward (see p. 223), and a like section, but smaller and much hidden, occurred (in 1871) at an abandoned brickyard not a quarter of a mile to the south-east, the beds being as follows:—

London Clay { Brown clay, a few feet.  
Clayey pebble-bed (basement-bed), 2 feet or more.  
Oldhaven Beds. Sand apparently.

By the northern side of the old earthwork in Holwood Park there is a small patch of London Clay, which seems to come on abruptly and irregularly over the Blackheath pebble-beds. In the field between the earthwork and the cottage-garden, just north, there is the hollow left by an old clay-pit, close to which, and at a higher level, the pebble-beds are bare.

There are also signs of a smaller patch a little to the north, along the foot-path at the edge of the park.

*Bickley.*—A large outlier stretches southward from Bickley Park to Brasted Green, with an average breadth of about a mile. The small spur that stretches across the railway into what was once Bickley Park is almost separated from the rest, and indeed was at first mapped as separate. There used to be, at the southern part of the park, an old gravel-pit, showing a clayey sort of gravel (? basement-bed) over a more sandy pebble-bed, and the neighbouring railway-cutting laid open a long junction-section (see Fig. 40, p. 225), another being shown in a brickyard further eastward, and a third by the railway still further east, where at top there is clay, with a clayey pebble-bed at its base.

The shallow cutting of the Lewisham and Tunbridge (South Eastern) Railway, on the western side of Hawker Wood, is in London Clay, and also the next one southward; but there were no other sections, and both the eastern and western boundaries are rather doubtful.

At Brasted Green the London Clay seems to end off rather abruptly, and the Blackheath Beds at once rise southward to a higher level. A well in a market-garden, about a third of a mile north-east of the Union House, was dug through about 40 feet of clay, to pebbles.

Close by this outlier, and about three quarters of a mile north of Farnborough, there seem to be two very small detached patches; and there may be another on the road between Crofton and Crofton Court.

At Chiselhurst again there seems to be a small patch of clay a little east of the church. North of Perry Street, and in Kemnal Wood are rather larger outliers. In this neighbourhood there may be more dots of London Clay, left in hollows in the Blackheath Beds.

*Elmsted.*—Between Chiselhurst and Eltham is a large and thick outlier, coming on with a marked feature above the Blackheath Beds on the south, but with a more doubtful boundary in the lower ground on the north, and almost joining the main mass on the north-west.

The only sections were in the brickyard near Chiselhurst, in that at Pope Street, in the railway-cutting north of Sundridge Park (see Fig. 41, p. 226), and in the long cutting, on the Lewisham and Dartford Railway, east of the Eltham Station, which is in London Clay, with a little drifted loam and gravel at the shallow western end. In the clay there are some layers of brown and grey loam, which, westward of the first bridge, showed an easterly dip increasing from nearly nothing to 6° and then decreasing; east of that bridge they were also shown, are regular and continuous, and prove that the beds rise slightly eastward and then fall (at an angle of 2° to 3°). At Pope Street there is a thin capping of resorted gravel for a short way, and at the eastern end there are a few small hollows of gravel over the grey clay.

The London Clay was also shown in the next cutting eastward, between the above and Sidcup Station (Lamb Abbey), which is short and shallow. At Longlands a thickness of 18 feet of clay was found in the pits of the brickyard, now given up, at the back (or north) of the house, and northward the clay seems to stretch across the road.

South of the Sidcup Station there is a small patch; clay was found at the houses on the southern side of the lane, and a shallow well at the back of one of them passed through clay and a clayey pebble-bed (basement-bed) to sand.

The railway cuts through the edge of a larger mass at Bushey Leas Wood see Figs. 15, 44, pp. 140, 228).

At the southern and highest part of the brickyard on the north of the high road at the eastern end of Bexley New Town the sandy pebble-bed of the Blackheath Series was shown (in 1863); whilst down the hollow a resorted brown clay occurred above this, with a thin clayey pebble-bed dividing the two. It would seem therefore that there is here a small patch of London Clay resting in a hollow in the Blackheath Beds. A little to the west there seems to be another.

An outlier runs for a mile from near Welling eastward, on the south of the high road, nearly joining the main mass in Danson Park.

A smaller one occurs between New Bexley and East Wickham, and at Bostal Heath there is a still smaller patch of London Clay, of which however no section occurred when it was mapped, but in 1870 a small pit was open in grey clay, 3 or 4 feet thick, underlain by brown loam with "race" and shells, apparently grey and more sandy lower down, but shown to little more than a foot deep. This loam is just like the "basement-bed" in Berks, &c.

At Woolwich there is a small patch, at the brickyard about half a mile southward of the Royal Artillery Barracks (see p. 147).

The patch at Widmore Kiln, Bromley (Fig. 39, p. 222) is too small to be mapable, as also is that at the western end of the great Erith Sand-pit (p. 231).

### *South London.*

North of Catford Bridge the boundary-line of the London Clay rises up from beneath the gravel of the Ravensbourne, and runs irregularly northward to Deptford, being affected by the fault between that place and Lewisham.

From Deptford the London Clay has been cut back westward, by Peckham and Dulwich, forming the high ground of Forest Hill, &c., and rising well above the bay of the Woolwich Beds at Dulwich Hill, Tulse Hill, Herne Hill, and Champion Hill. The boundary-line here is however somewhat doubtful, and this formation may perhaps stretch across from Herne Hill to Dulwich Hill.

At Camberwell the boundary-line turns northward to the Thames near Bermondsey, but as in this course everything is hidden by the Valley Gravel the only evidence is got from well-sections and borings.

From London westward the London Clay rises up from the Valley Gravel south of the Thames and forms Brixton and Streatham Hills.

Good junction-sections with the Woolwich Beds have been made in the Counter Hill brickyard (now a thing of the past) and in the cutting on the London and Brighton Railway south of New Cross (see pp. 155-157).

The borings along the course of the Effra Branch Sewer, near Dulwich College and in the Five Fields (see *post*), passed through the London Clay to the Woolwich Beds, and thereby served as a guide in drawing the line between the two formations.

At the brickyard near Brookwell Hall the junction of the London Clay and the Woolwich Beds is shown (see p. 160). The section is remarkable for the absence of the basement-bed.

A little south of this brickyard is another in London Clay alone, as also are both mouths of the neighbouring tunnel of the Peckham and Sutton (London Brighton and South Coast) Railway.

At the south-western foot of Herne Hill, in the brook that runs thence along the eastern side of Brixton, there is stiff dark brown London Clay,

which is capped by gravel a little further toward Brixton. This is at a lower level than the neighbouring outcrop of the Woolwich Beds.

MR. H. BAUERMAN tells me that in making the sewer at Tulse Hill great numbers of *septaria* were found, and were used for road-making.

There is but one outlier in this tract, at the top part of Loam Pit Hill, west of Lewisham, the sections of which have been already described (see pp. 153-155).

*Northern Side of the Thames, from London to Stanford-le-hope.*

The course of the boundary-line of the London Clay across the Thames from Rotherhithe is uncertain, on account of the covering of alluvium and of Valley Drift. It seems however to run through the West India Docks, and may then run northward up the bottom of the Valley of the Lea, or, on the other hand, it may continue eastward, under the marshes, leaving the uprise of the Oldhaven and Woolwich Beds at Stratford as an inlier (see p. 168).

MR. J. E. GREENHILL watched the excavations for sewers along the side of the valley of the Lea, in Hackney, and he tells me that the clay, beneath the gravel, was in many parts only 10 feet thick, when the pebbles, etc. were reached. A specimen that he sent me is a very calcareous sandstone, crowded with glauconite-grains, with many shells (? *Cyprina* or *Cytherea*), and with a few flint-pebbles. This seems to belong to the basement-bed. This gentleman has also sent me the following section, "in Mr. Lee's brickfield, close to [E. of] Clapton Railway Station":—

[River Drift.]	{	Brick-earth, with land and freshwater shells, teeth and bones of elephant, rhinoceros, &c. ; 16 feet.
		Sand and fine gravel, with occasional Palæolithic flint-implements ; 8 feet.

London Clay, with occasional specimens of *Lamna elegans*, passing down into a mottled clay and gradually into Woolwich Beds [?] Oyster-bed 18 feet down [? basement-bed].

The London Clay seems to have been touched, beneath the gravel, in some of the borings along the line of the Northern Outfall Sewer, across Plaistow and East Ham Levels (see *post*), and it was proved in the second well at the Beckton Gasworks (see Well-sections).

From near Barking Creek to near Rainham Creek it is likely that the boundary-line is under the river : at all events no sign of the formation was found in the Grossness borings, on the south (see *post*) ; and from Rainham Creek it would run beneath the marsh to Wennington. The formation then rises from the low ground, and its boundary runs from Wennington eastward by Aveley, Stifford, Orsett, and Horndon-on-the-Hill to Stanford-le-Hope, northward of which line the broad tract of clay, with its Drift cappings, stretches right across the county, to the other side of the London Basin.

There must be a fair dip northward from Wennington to Horndon, and eastward of the latter place the formation again sinks till lost below Stanford Marsh.

Along the above line only one section of the junction, with the underlying beds, was seen, at the brickyard about a mile E.N.E. of Stifford Church, where

the following section of the bottom part of the London Clay was laid open in 1863:—

Clayey-soil, with a few pebbles and flints. } 5 or 6 feet.  
Brown clay.

Basement-bed.—Brown clayey sand and sandy clay (as in Berks, &c.), with green grains; in parts broken-up bivalve shells, and also teeth of *Lamna*; from 3 to 6 feet shown. I was told that there were pebbles at the bottom part of this, and beneath them:—

Sand (of the Woolwich Beds).

At the shallow eastern end of the section the basement-bed was seen to rise up suddenly 3 or 4 feet, perhaps through a small fault.

MR. H. W. BRISTOW noted that "between the high road and the railway, about a mile south-west of Vange, bricks and tiles have been made from stiff brown and bluish-grey clay, with septarian balls, and here and there a layer or small lump of ferruginous earth, resulting from decomposed pyrites. In the railway-cutting there are slips, especially on the southern side. On the northern side a well has been bored to a depth of more than 200 feet, but the supply of water seems small."

### *Kent, East of the Cray.*

In this tract the London Clay has been eroded away for some miles, except for a few outliers, the most westerly of which will be noticed before returning to the main mass and to those bordering it.

*Swanscomb Outlier.*—On this large mass of the Tertiary beds are three cappings of London Clay, the most northerly of which makes a marked feature, and is partly covered by pebble-gravel.

Along the edge of Swanscomb Park Wood (Grovefield Wood), more than half a mile south-west of Swanscomb, there is drifted London Clay at the eastern corner, whilst a few yards westward brown sand (of the Woolwich Beds) occurs, and still further (and a little higher) the outcrop of a bed of black flint-pebbles shows the junction. Again, lower down there is sand, and then, as the ground rises up to the footpath, the London Clay comes on and forms the higher ground west of the path. Before getting to the western corner of the wood the pebbles again crop out, with brown sand below, and then, lower down and just by the corner, the shelly clays of the Woolwich Beds.

The black pebbles also crop out at the most northern edge of the wood, close to the village, and at the eastern edge, which however is not now as it is engraved on the old Ordnance Map.

West of Betsam another well-marked outlier occurs, and in the woods still further west a small one with a doubtful boundary.

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When the London Clay sinks under the Essex marshes, south-eastward of Stanford-le-hope, its boundary-line must soon reach the Thames, and probably runs beneath the river for some way, the base of the formation being 118½ feet down in the Thames Haven well (*post*). The line then crosses under the marshes on the Kentish side of the river, to the base of Northwood Hill, High Halstow.

From this point eastward the London Clay rises up to the south, from beneath the alluvium and its border of gravel, and

occurs in the greater part of the district known as the Hundred of Hoo, but is covered by gravel over a good part of the higher ground.

Binney and the Isle of Grain consist of London Clay, capped by gravel and surrounded by alluvium, part of the latter island having been cut off however at the combined estuary of the Thames and Medway.

Starting from Northwood Hill, the boundary-line closely follows that of the Oldhaven Beds in its course along the hills, by High Halstow and thence westward toward Higham, where it turns south-eastward, out of our district, to the Medway.

The northern slope of Lodge Hill, south of Cooling, is much broken by slips, and the like has happened in other places, sometimes making the boundary-line doubtful.

South-west of Higham is an outlier the greater part of which is either hidden under the alluvium of the Thames or masked by gravel. The south-eastern part is however clear and there is a section of the clay, with septaria, in the railway-cutting nearly a mile from the church (see also p. 235). The northern part is separated, as an island, by a narrow strip of alluvium, and the small railway-cutting through this island, westward of Higham, showed brown London Clay, with race.

A very small patch occurs close to the main mass south-east of Cooling, judging from the clayey nature of the ground.



CHAPTER 16. LONDON CLAY—*continued.*

## NORTHERN BORDER OF THE LONDON BASIN.

*Berkshire, Main Mass.*

On the west of the Loddon the junction of the London Clay and the Reading Beds is hidden by gravel, but it seems to run parallel with that of the latter formation and the Chalk, and at a distance of nearly half a mile from it.

On the other side of the river the boundary-line is also hidden by the gravel at Hurst, whence it runs, in a general east-north-easterly direction, to Holyport, south of Maidenhead, again to pass under the gravel and alluvium in its further north-easterly course by Dorney to Farnham Royal.

On the southern side of the Windsor inlier, through the sharp local northerly dip, it comes near to the boundary of the Reading Beds, and follows the latter round the base of the Chalk hill and across the Thames to Datchet.

On the south of its boundary-line the London Clay forms gently-rising hills, above which, in Windsor Great Park, the Bagshot Sand comes on, whilst on the west there are patches of gravel on some of the higher ground.

Nearly three quarters of a mile S.W. of Haines Hill a section of the basement-bed was shown in 1858, in the ditch, then freshly cut, on the western side of the road leading to Hurst Green. Near the cross-roads there was clayey sand with *Ditrupe*, *Ostrea*, *Pectunculus*, and other shells, and flint-pebbles; further towards the Green there was brown clay with "race" (irregular-shaped calcareous concretions); beyond this light-bluish-grey and brown mottled loam; then brownish sand with flint-pebbles; and farther still the same without pebbles. I could not make out the superposition of the different members of the basement-bed here, but it is clear that together they take up a great space at the surface.

I was told that in making a well at Haines Hill this bed, with shells of *Ditrupe*, was found at a depth of about 35 feet; and on the road three quarters of a mile to the N.E., there are many black flint-pebbles in the ditch, most likely from the basement-bed. Hence eastward toward Bray the boundary-line of the London Clay follows that of the Reading Beds at a distance rarely greater than a mile, or less than half a mile.

Just south of Paley Street the channel of Bray Cut passes through the junction with the Reading Beds. The section is now much hidden, but at one part I saw the succession given on p. 179.

Of course it is likely that these details would not hold over a great length of section, indeed my colleague MR. T. R. POLWHELE had years before made the following note:—

"In the cut made to drain Ruscomb Lake the following section was shown near the bridge on the road from Paley Street to Cox's Bridge:—"

				FEET.
Clayey drift	-	-	-	- 2
London Clay.	{	Clay	-	- 5
		{	Loam with layers of clay and shells, here and there pebbles	-
	Pebbles and oyster-shells		-	- 1
	Sand, in places hardened into stone		-	- 2
	Bed of <i>Ditrupe</i> , 2 inches.			

"A little to the west several pebble-beds may be seen in the section."

The basement-bed, with *Ditropa*, was again shown at the brickyard at Stud Green (p. 179), and in the neighbourhood above described it seems to have a rather broad outcrop, judging from the loamy nature of the soil.

MR. POLWHELE again notes that "close to Bourne Bridge, more than two miles south of Maidenhead, there is a section of a hard slab-like sandstone."

In 1821 MR. H. WARBURTON noticed a set of fossils from the sandstone in the basement-bed, and made the following remarks on the section that yielded them:—"The place from which these stony concretions were taken is the watercourse lately made for draining the newly-inclosed lands of Windsor Forest, on the road that leads from Holyport to Binfield. The sand with its concretions there rests upon variegated plastic clay."\* A list of these fossils is given at p. 264, with many additions from parts of the same section. MR. C. KERRY tells us that, "during the formation of the 'Cut' in 1819, a stratum of calcareous stone, which had to be blasted with gunpowder, was found near Touchin End; and between Paley Street and Brick Bridge, a layer of oyster-shells was discovered of a large and fine description."†

"In some ferruginous sand thrown out of a pond near the cottage a quarter of a mile west of Mount Scipput, I saw a quantity of *Ditropa* and a few oyster-shells, showing the presence here of the basement-bed." (MR. POLWHELE'S Notes.)

The brickyard a little east of the Cavalry Barracks at Windsor is in London Clay, but the junction with the Reading Beds, between this and the Castle, is not shown.

"In the brickyard south of Warfield, the upper bed of the London Clay (with septaria, full of fossils) may be seen, and above it the passage-bed from this formation to the overlying Bagshot Sand." (MR. POLWHELE'S Notes.)

There is a tile-kiln at Egham, to which the following remarks of MR. WARBURTON most likely refer: "In the clay-pits to the south of the Great Western road, near the foot of the hill, the clay is seen characterized by its blue colour, by many of the most common of its fossil shells, and by its septaria."‡

Where the London Clay crops out from beneath the Bagshot Sand, its sandy top part may sometimes be seen, as on the south-west of Cranbourn Wood, and there was a good section of these passage-beds between the two formations at an old brickyard in Windsor Great Park, more than a quarter of a mile N.E. of Bishop's Gate, where a pit more than 15 feet deep showed thin alternations of brown and light-coloured sand with pale grey clay, the lower part being more of a brown loam, whilst below there seems to be clay, judging from springs, &c.

### *Berkshire, Outliers.*

The large Wargrave Tertiary outlier, as before noticed, is in great measure formed of London Clay, which occurs as two large and two or three small outliers.

The largest of these forms Bowsey Hill, and the boundary of this thick mass follows the line between the Reading Beds and the Chalk from Bear Hill to the south-east of Warren Row, generally at a distance of about a quarter of a mile, but with a more winding course.

Along the road rather more than half a mile east of Chamberlain's Farm the basement-bed is shown, and in it is a bed of flaggy sandstone at least a foot thick; a little further north, on the same road, just beyond the road turning off to Crazy Hill, I saw the brown loam of this bed (and just below it the sand of the underlying formation); and also less than a quarter of a mile S.E. of Scotland.

Thence eastward the clayey nature of the soil, as contrasted with the sandy soil here formed by the upper part of the Reading Beds, marks the boundary.

\* *Trans. Geol. Soc.*, ser. 2, vol. i. p. 52.

† *The History and Antiquities of the Hundred of Bray.* 8vo. Lond. 1861.

‡ *Trans. Geol. Soc.*, ser. 2, vol. i. p. 49.

The loamy basement-bed occurs again however by the lane about half a mile N.W. of Knowl Hill Church; there is a section of it at the brickyard north of Bear Hill (see p. 181), and I also saw it about a quarter of a mile to the south, just above the house.

The other large outlier, forming Ashley Hill, has a less winding boundary, in like manner however following that of the Reading Beds. There was no section anywhere; but the basement-bed is shown on the road half a mile S.S.W. of Hall Place. At the south-western boundary there seem to have been some small landlips.

The highest parts of both Bowsey and Ashley Hills are capped by pebble-gravel.

There seems to be a thin capping of the basement-bed on the top of Knowl Hill, but I cannot be certain about it; half a mile to the west there is a rather larger outlier, also somewhat doubtful; and between Littlewick Green and Ashley Hill is a very small one.

On the highest part of the Cookham Dean outlier (p. 182), there is a small patch of London Clay.

#### *Between the Thames and the Colne, Buckinghamshire, Main Mass.*

From Dorney north-eastward beyond Stoke Poges all is hidden by the gravel, which creeps up from the river, by a succession of slopes and terraces, to a much higher level; further than this too, the higher gravel of Stoke Common, &c. makes the line very doubtful as far as Hedgerley.

From Hedgerley eastward the London Clay is cut through by the valley to beyond Fulmer. Then, still covered with gravel, it spreads out northward to Gerard's Cross Common, where it is again cut back, by the valley of the Misbourn, to Red Hill, Denham, whence the boundary-line slopes down to a lower level southward for about a mile, and sinks below the gravel of the Colne. It would have taken but a little more denudation along the Fulmer Valley to have detached the mass on the north, as an outlier.

At Hedgerley there was once a fine section, from the London Clay to the Chalk (see p. 189). PROF. PRESTWICH remarked "the abundance and fine state of preservation" of the fossils of the basement-bed here (see list at p. 264), and that "the concretionary calcareous masses (containing the fossils) have a brown and weathered appearance, and have been here and there bored into by some mollusk. These blocks are literally full of shells, amongst which the *Cardium* n. sp. (P. *C. Laytoni*, Mor.), *Cytherea obliqua*, *Natica glaucinoides* (= *N. labellata*, Lam.), *Nucula*, *Rostellaria* (= *Aporrhais*) *Sowerbyi*, and the *Ditrupea plana*, are most abundant. The shells are well preserved, some with their nacre, but their substance is rather soft and friable."

#### *Buckinghamshire, Outliers.*

Some of the outlying patches in this county are many miles off the main mass, and, though mostly very small, they have some interest, as extending the area over which the formation occurs.

On the Lane End outlier (p. 183) there are six patches of London Clay, the most marked of them forming the hill on the west of the village and being the central part of the whole outlier.

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\* *Quart. Journ. Geol. Soc.*, vol. vi. p. 268.

On the Common by the road there was a pit showing the basement-bed over the Reading Beds. There were many septaria lying about, some (with casts of fossils) from the basement-bed; and there were also, from that bed, some small thin pieces of sandstone, and some of concretionary calcareous sandstone, on which last there are often adherent shells of *Ditrupa*.\* In the London Clay itself, which is shown close by, there are fossils; but they are much broken up. Again, in some small pits on the Common S.W. of Lane End, the basement-bed may be seen overlying the Reading Beds, and the clay is shown higher up.

The presence of London Clay on Park Hill, the other high point of the Lane End outlier, was inferred from the height of the ground; there being no section at the time the Survey was made.

In a pit at the kiln near Mozzels a very irregular junction of the basement-bed with the Reading Beds was seen in 1859 (see p. 184). The former must merely fill a hollow in the latter, as sand seems to have been found on all sides.

At the northern end of Moor Common there were some sections of the London Clay, with a few nodular masses of soft sandstone (with indistinct fossils) and of ironstone. The basement-bed seemed to come in at the lower part; but the whole had a disturbed irregular look and was close to one of the faults that I have been obliged to map (see p. 185). At the top there is a bed of clay, most likely reconstructed London Clay, with a layer of small flint-pebbles at the bottom, and resting directly on the true London Clay.

In the wood just N.W. of the above there is most likely a little of this formation, judging by the height of the ground.

Spreading over the central and southern part of Moor Common is a larger mass, the sections in which have been described before. This may possibly join on to the next outlier on the north.

A list of the fossils from the basement-bed at Lane End is given at p. 264.

At Penn a small patch escaped me when first in that neighbourhood, but in 1869, whilst examining the drift-mapping with SIR A. RAMSAY, I noticed a very small cutting in brown clay, underlain by the brown loam of the basement-bed, in the narrow lane about half a mile west of the church.

The higher part of the Coleshill outlier (p. 190) is formed of London Clay, the boundary-line of which follows that of the Reading Beds from Coleshill Green north-eastward. At the Green the following section was seen, in a well that was being made, in 1859:—

Gravel of flint-pebbles.

A little bluish-grey clay, London Clay (P).

Basement-bed; light-brown loam, 14 feet shown, no pebbles found.

The end of the work was not seen. There is light bluish-grey London Clay on the Common near by.

At the bend of the road about two thirds of a mile to the north there are many flint-pebbles, most likely from the basement-bed.

The section in Brentford Wood has been given before (p. 190). The basement-bed is shown also just north of the kiln. The water that is thrown out from this more or less sandy bed, at its junction with the clay of the Reading Beds, is mostly lost in the swallow-holes at the junction of the latter formation with the Chalk.

At the Frog Hall outlier the only section of the London Clay seen was at the brickyard (see p. 191).

The highest part of the Cowcroft outlier, Chesham (p. 194), is formed of this formation. The upper pit, at the kiln, showed about 15 feet of brown roughly-laminated London Clay, with septaria, above the brown loam of the basement-bed, the fossils from which latter are noticed at p. 264. According to the section given by PROF. PRESTWICH† the bottom 3 feet of the London Clay consists of "layers of laminated grey and brown clay," and the basement-bed, which I was unable to see clearly, of a "layer of imperfect septaria full of

\* There is a specimen of this in the Jermyn Street Museum. See "Catalogue of Rock Specimens," Ed. 3, p. 166.

† *Quart. Journ. Geol. Soc.*, vol. x. p. 90.

fossils, half a foot; light brown sandy clay, 2 feet; flint-pebbles in clay, a foot," in descending order.

### *Hertfordshire and Part of Middlesex.*

On the eastern side of the Colne the London Clay plays a more important part in the shape of the ground than to the west, as it forms the greater part of the well-marked Tertiary escarpment that reaches from the Colne to the Lea. Its boundary-line rises from below the alluvium, at a spot about a mile and a half north of Uxbridge, and follows that of the underlying Reading Beds, excepting where the latter formation runs out in spurs over the Chalk.

MR. TRENCH notes that "at the western corner of the wood just south-east of Harefield Grove, the basement-bed was shown in a saw-pit," and it also occurs at Woodcock Hill Kiln (see p. 195). In the high road at Park Farm, south of Rickmansworth, there is some clay much like London Clay; and in draining the fields near Aston's Lodge, in the lower ground just east of Batchworth Heath, both the clay and the basement-bed (brown loam) were often met with (see p. 197).

About half a mile south of Batchworth Heath, and near the outcrop of the Reading Beds (see p. 197), the basin dug for an ornamental pond in a small new park showed, in 1862, a section of London Clay, nowhere much over 8 feet thick, above the basement-bed. The latter consisted of the usual brown loam, with shells and a few flint-pebbles; the shells (a list of which is given at p. 264) mostly in layers, one of which was a very hard stone, and was marked by an abundance of *Cyprina*; another, lower down, was a more septarian-like stone, full of casts of *Panopæa*; and lower still was another rather hard bed. The most remarkable fossil perhaps was the *Cytherea orbicularis*, a shell that has been but rarely found I believe in this bed, though plentiful in the sand next below the London Clay in parts of East Kent, but of which I got some very good specimens here.

The basement-bed is also shown at other parts near here, and at the Pinner inlier it has been found in sinking shafts to the Chalk (see p. 206).

The following notes of cuttings on the Rickmansworth and Pinner (Metropolitan Extension) Railway, were got by MR. RHODES from the Engineer:—In the long cutting (No. 5) eastward of The Grove and Green Lane Farm, which is 50 feet deep at most, there was blue clay, yellowish at top, with selenite throughout, and with occasional ferruginous nodules; but no fossils were noticed.

The cutting (No. 6) south of Northwood Station was in like clay, to the depth of 12 feet, and so were the shallow cuttings (7 and 8) W. and W.N.W. of Pinner Green.

The London Clay and its basement-bed were both cut through in the railway-cutting at Bushey (see p. 198). The section is now hidden, but a list of the fossils that were found in the basement-bed is given at p. 264. In the next cutting to the south these beds are again shown, not clearly however, and here also, according to MR. TRENCH'S Notes, "there are fossils and some clayey sandstone with lithodomus-borings like that at Watford Heath Kiln."

The basement-bed is touched at the brickyard at Chalk Hill, where the pebble-bed at its top was seen, in 1887, and was found to be thinner than at Bushey Kiln, to the N.E.; and there are good sections of it at Bushey Kiln, where the junction with the Reading Beds is even, and at Watford Heath Kiln (see p. 203). In the section at the last place the topmost bed that has been classed with the basement-bed may perhaps more strictly be a passage from that bed to the London Clay proper.

In draining the fields a little south of Bushey the London Clay was found close to and on the southern side of the brook, due south of the church: whilst a very little lower down the valley, or to the west, the brown loam of the basement-bed was shown (1862).

We must now travel some way on our north-easterly journey along the Tertiary escarpment before coming to any good section of this formation. There are however some small signs of the basement-bed here and there: thus by the road-side south-east of Patchets Green, south of Aldenham, just before reaching the lane to Burnt Farm, there is some of the usual brown loam; and the like was found in making drains just south of New Organ Hall, east of Aldenham (see p. 200).

The London Clay is shown on the high road at Ridge Hill, between London Colney and South Mims. At Rabley brickyard, on the south, the brown loamy basement-bed occurs at the kiln, close by the road; and at Pink Farm brickyard, near by to the west, Mr. TRENCH notes that "there is brown London Clay, about 8 feet thick, over some 2 feet of the brown sandy clay of the basement-bed. It is said to be 30 feet more down to the Chalk."

"There are signs of the basement-bed about a third of a mile nearly south-west of Mims Hall, on the southern side of the road; and in the cutting of the Great Northern Railway west of Friday Grove." Nearly the whole of this cutting is in the London Clay itself.

Hence northward to Hatfield Park there were no sections, and the hills of London Clay are much covered with gravel; but east of the park the pits at the kiln show the junction with the Reading Beds (see p. 205). The basement-bed is here made up of many layers, the olive-green sands being the most remarkable. The fossils were so frail that I could not get one in anything like a perfect state. PROF. PRESTWICH says "the only fossils I could here determine were an *Astarte* (*Cytherea*?), *Ostrea*, and teeth of *Lamna*."\* I can add to these a *Cyprina*.

Between Hatfield and Hertford the Boulder Clay generally overlaps the junction with the Reading Beds, and makes the boundary-line doubtful.

At the northern end of the Northaw inlier of the Reading Beds there is some clayey sand in the road, rather more than ten chains N.E. of the brook, and in a field just by, on the eastern side, there is loam with green grains and flint-pebbles. These most likely belong to the basement-bed.

At the Bennet's End outlier (see p. 208) a small patch of London Clay is brought in by the fault, which, at the southern brickyard, has thrown this formation against the Chalk, as shown in fig. 36. The fossils that have been found here, by DR. J. EVANS and by myself, of which a list is given at p. 264, were chiefly from the upper loam, that below the pebbles yielding comparatively few; but at the newer pit a shell-bed has been found below the pebbles, and there were lying about some pieces of fossil-bearing sandstone from near the bottom of the basement-bed. At one side of the newer pit the brown London Clay fills a hollow scooped out in the loamy basement-bed, almost down to the underlying plastic clay. The pebbles are not wholly confined to the marked layer in the middle of the basement-bed, there being a few small ones scattered through the loam and in the sandy shell-bed. DR. EVANS has found fossils in the loam at the southern part of the other brickyard.

## CENTRAL TRACT.

### *Middlesex.*

Leaving the border-belt, we will turn to the broad tract between it and the Thames.

Southwards from the escarpment to the district of the gravel and brick-earth of the Thames Valley, that is to a line from Uxbridge to London, there are many sections of the London Clay, in railway-cuttings and in brick-yards, most of which do not call for remarks. On the higher grounds this formation is mostly capped by gravel, and the gravel of the Thames Valley is sometimes cut through to it.

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\* *Quart. Journ. Geol. Soc.*, vol. vi. p. 270.

There are also well-sections through this formation (see *post*), which show the presence of the basement-bed, with a thickness of from a foot to five feet, and composed of various proportions of sand, clay, and rock, with pebbles and shells.

In the well at the Lower Heath, Hampstead, fossils were found in this bed (285 feet below the surface), for a list of which see p. 264. In his description of this section MR. WETHERELL says that the lower part of the London Clay "abounded with vegetable remains in a compressed and decomposing state. . . . Between the London and plastic clays a hard rock, 5 feet thick, was bored through. It abounded with green siliceous particles, and contained numerous shells, disposed in layers . . . . In some parts of the rock were layers of calcareous spar, the surface of which was beautifully studded with crystals of pyrites. The bed contained a great many rounded flint-pebbles, some of which were in a decomposing state: and a few of the same pebbles were imbedded in the lower part of the London Clay."\*

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*Ealing, &c.*—MR. J. A. BROWN, who has carefully watched excavations in this neighbourhood, has printed a short list of the fossils found in the London Clay,† and directly after its publication he wrote to tell me that he had just met with fossils in his upper zone, which would have added to this list. The special interest of the find, on the western slope of Castlebar Hill, at a height of 150 to 155 feet above Ordnance Datum, lies in the occurrence of a band of *Corbula* (P. *C. globosa*), concreted with ferruginous sandy clay, a few inches thick and broken up into detached masses.

It seems that the bedded loam and sandy clay at The Mount, which MR. BROWN has described (see p. 308) may possibly belong to the London Clay rather than to the Drift, for no Drift bed is known elsewhere beneath the pebbly gravel, which has always been found to rest on the London Clay or on the Bagshot Sand, without anything coming in between.

The occurrence however of masses of Sarsen stones in this sandy clay seems against this view, and there is a peculiarity in the dip, for MR. BROWN has recorded a southerly dip in the smaller southern reservoir, whereas, when he took me to the larger northern one, in 1887, there was a slight northerly dip, roughly following the slope of the ground, as also would be the case down the southern slope.

*Hampstead.*—The following remarks on the London Clay, etc. of this place are taken from a paper by MR. C. EVANS,‡ whose residence there enabled him to watch the progress of the sewerage-works.

In 1871 "excavations were commenced in the Finchley Road, near Child's Hill, for the purpose of connecting the houses at Burgess Hill with the main line of sewer . . . at the southern end to a depth of 31 feet, and at the north end of the drain to about 16 feet." The top bed was a yellowish or ochreous clayey sand, with a few casts of shells. This was 12 feet thick, and passed down into dark grey clayey sand, which, in its turn passed down into sandy clay. In the last "nodules of septaria and of iron pyrites were not very numerous . . . but . . . shells were in great abundance [and well preserved]. Of these a few species were present in great numbers, and were highly characteristic, belonging to forms rare in the lower part of the London Clay." The commonest were *Voluta nodosa* and *Pectunculus decussatus*; and "a small and very delicate echinoderm was not uncommon. The whole fauna . . . indicates a deposit formed not very far from land under a depth of water of about 50 fathoms." In the deepest part this sandy clay was seen to pass down into dark stiff clay.

In 1866 a sewer was made, to connect "the northern and western sides of Hampstead with the . . . Metropolitan Main Drainage System. This

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\* *Trans. Geol. Soc.*, ser. 2, vol. v. pp. 131–33.

† *Ann. Rep. Ealing Micr. Nat. Hist. Soc.* 1886, pp. 15, 16.

‡ *Proc. Geol. Assoc.*, vol. iii., no. 1, pp. 23–27. (1873.)

sewer, commencing at North End, was formed across the north-west side of Hampstead Heath, and along Platt's Lane and the Finchley Road to West End."

"On the high ground, at the hill overlooking Child's Hill the excavations passed through the yellow Bagshot Sand, but in descending the hill towards the Finchley Road this " became more clayey and yielded much water, the upper part of the wet sand being yellowish-brown, the lower dark grey. "Lower down the hill the dark grey sand passed into a sandy clay, which was drier and contained fossils in great numbers. This . . . extended along Platt's Lane and the Finchley Road nearly to New West End . . . Across the Heath, between Child's Hill and North End, the sewers traversed the grey water-bearing stratum," and the fossiliferous bed was reached only in the swampy ground by the Leg of Mutton Pond.

"A similar succession . . . was seen in 1862, in drainage works in Froggnal Lane. The upper part of this exposure showed the yellow Bagshot Sand at Froggnal House. Lower down . . . near the entrance gate to Oakhill Park, the dark grey sand was seen, and at the corner of the lane leading to the parish church and near the Priory the sandy clay," with fossils.

A comparison of these with other sections "gives a thickness of about 50 feet to the sandy clay with *Voluta* and *Pectunculus* . . . and there can be no doubt that it forms [at its outcrop] a continuous band underlying the Bagshot Sand as far as and also, to the east of Highgate," but has been eroded from all but the higher ground round London.

The tunnel on the Midland Railway, south of Hampstead, is in stiff "dark grey clay, with many zones of septaria and much iron pyrites," with "a group of fossils very distinct from those of the sandy clay above . . . the most abundant species belong to such genera as *Nautilus*, *Leda*, *Nucula*, *Corbula*, *Pholadomya*, *Cyprina*, &c., *Fusus*, *Pleurotoma*, and other gasteropods are present, but the species are mostly distinct from those of the " higher bed. When examining this railway I was struck with the abundance of *Pholadomya margaritacea* in some of the spoil-heaps.

"The characteristic species of the lower bed indicate, apparently, a greater depth of water . . . and a similar group of deep sea shells has been obtained . . . from the tunnel on the Great Northern Railway, near the Islington Cattle Market . . . from that near Primrose Hill, and . . . from the tunnel under Sydenham Hill," on the London Chatham and Dover Railway. On the map that accompanies this paper the outcrop of the sandy clay, from beneath the Bagshot Sand, is shown, on a large scale.

*Highgate.*—There are two tunnels through the London Clay on the Edgware Highgate and London Railway at Highgate. At the northern mouth of the more northerly one I was much surprised to see (on the western side) some buff and yellow sand in the clay: it occurred mostly so as to form very fine alternations of sand and clay, showing a dip of 30° to 35° along the line S.E., which however seemed to hold but for a short way, and must be merely false-bedding, a thing which I had never before seen, or heard of, in this formation, a deposit of a fairly deep sea.

At the northern mouth of the other tunnel there is a wash of loam and pebbles above dark grey sandy London Clay; and at the southern mouth some clayey greensand is scattered in the sandy clay near the bottom. More of this sand has been found in the tunnel, and many beautiful fossils have been got from it.

The deep cutting, on the same railway, south of Crouch End showed at the top (at the eastern end) brown and rather sandy clay, the uppermost part of the London Clay, whilst below was grey clay very full of fossils, chiefly *Pectunculus decussatus*, and with septaria, selenite and iron-pyrites. Further westward, where the work was going on at the time of my visit, the lowermost clay was very dark, and there was a lenticular layer of green-grey finely laminated sand close to the bottom. The small cutting just west is in rather sandy brown clay.

The cutting for the Archway Road, just southward, has yielded very many beautiful fossils from the upper part of the London Clay. "The first attempt at Highgate was to drive a tunnel through the hill; but after a tunnel of small dimensions had been driven, this plan was abandoned in consequence



of finding the substratum sandy and loose, and incapable of supporting an arch of the dimensions required, and resisting the superincumbent and lateral pressure.\* I have seen some of this sandy bed, in the collection of the late Mr. Wetherell: it is green, like that in the railway-tunnel, and also contained fossils. A neighbouring brickyard, north of the Archway, also yielded many fossils, which were largely secured by Mr. WETHERELL.

I think that PROF. PRESTWICH was mistaken in saying that the "beds of sandy clay," in which so many fossils were found "near the level of the road at the Archway, . . . are about 110 to 130 feet below the outlier of Bagshot Sands capping the hill."† The Bagshot Sand really comes on at the top of the cutting (see p. 269). PROF. PRESTWICH writes to say that he must have meant below the top of the sand.

Some time before joining the Geological Survey I made a note of the section shown in the New River Company's reservoir in Maiden Lane, south of Highgate: the excavation was wholly in clay and about 12 feet deep; the upper part of the clay was brown, the lower bluish-grey, and at the division (that is at the limit of the atmospheric decomposition) there was a bed of septaria.

The occurrence of the fossil resin Copaline, or Highgate Resin, in the London Clay here is noteworthy. It "is found in irregular pieces of a pale yellowish and dirty brown colour, resembling the resin copal in colour, lustre, transparency, hardness, and difficult solubility in alcohol,"‡ and it often occurs together with (and attached to) iron-pyrites.

### Essex.

Over the high grounds of Epping Forest the sandy top part of the London Clay occurs, showing the passage upward into the Bagshot Sand.

Thus at Loughton Camp, in the wood rather more than a mile northward from the Railway Station, but which (though a fairly distinct earthwork) is not shown on the six-inch Ordnance Map, loam and clayey sand are to be seen, whilst at Turpin's Cave, the northern and highest part of the work, there is some buff sand. My friend MR. T. V. HOLMES took me to this site in 1887, the Essex Field Club having cut a section across the rampart and mapped the earthwork.

A good section, at what is known as the Oakhill Pit, about a mile westward of Theydon Bois Station, has been described by MR. N. F. ROBARTS,§ who is disposed to regard the top beds here, and at the brickyard on the east (for the supply of which this pit must have been made) as of Bagshot age. When there, in 1887, I could not make out the distinct divisions noted by MR. ROBARTS, but was disposed to divide the beds in the large pit, which is just within the wood, as follows:—

Slight wash of sand and gravel.

Fine clayey sand, with thin layers of grey clay, several feet (? passage-beds).

Stiff clay, weathered brown in part, but grey deeper down (and stiffer); with decomposed septaria and ironstone.

MR. ROBARTS, who must have seen the section when in a clearer state, and must have spent much more time in it than I was able to, makes the following divisions, the greatest depth of the pit being 32 feet:—

\* CONYBEARE and PHILLIPS, "*Outlines of the Geology of England and Wales*," (1822), p. 25.

† *Quart. Journ. Geol. Soc.*, vol. x. p. 408.

‡ BRISTOW'S "*Glossary of Mineralogy*," p. 93.

§ *Trans. Essex Field Club*, vol. iii., pt. 8, pp. 234-236. (1884.)

- a. Sandy loam, with pebbles and subangular flints: up to 4 feet.
- b. Light-yellow Bagshot Sand. At the brickyard, not in the great pit.
- c. Reddish-yellow clayey sand. ? a remnant of the Bagshot:  $3\frac{1}{2}$  feet.
- d. Greenish pipe-clay, throwing out water from the sand above: 2 inches.
- e. Greenish sand: 2 or 3 inches.
- f. Mottled grey, reddish and fawn-coloured slightly sandy clay, with traces of lignite: 12 feet.
- g. Orange-coloured and white sand, with ironstone-concretions and traces of casts of fossils: an inch or two inches.
- h. Mottled grey, reddish and fawn-coloured sandy clay, with a band of sandy ironstone and some black traces, probably lignite: 3 feet.
- i. Black sandy clay, changing in places to olive-green. Fossils said to occur, but only a cast of a shell in iron-pyrites found. Pyrites abundant: seen to 12 feet.

The sand and loam at the brickyard, close by on the east, seemed to me as likely to belong to the passage-beds, rather than to the Bagshot Sand.

At the kiln three quarters of a mile north of Theydon Mount Church there were, in 1872, two pits giving a continuous section of the passage-beds from the London Clay to the Bagshot Sand, as below:—

Brown loam.

Clayey sand, fine, in parts a soft sand.

Brown loam, as above.

Stiff brown London Clay, with septaria at the lowest part.

The sandy top part of the London Clay may be well seen on the high ground at Epping, above the railway-station, in a pit in a brickyard nearly half a mile north-westward, where there is bedded brown sandy clay and clay, and in other pits near the brickyard just west of Coopersale Common, showing brown sandy clay and clayey sand, with clay further east and then Boulder Clay. MR. H. B. WOODWARD notes that "in the railway-cutting about half a mile east of North Weald Station a sandy loam rests on stiff London Clay."

MR. E. A. FITCH has reprinted a short note "probably from the 'Chelmsford Chronicle' of about 1838," according to which in the excavations for the railway "great quantities of submarine shells embedded in blue clay have been turned up at Brentwood. One lump of a ton weight [septaria?] was found."\*

MR. WOODWARD again notes that "the stiff London Clay with septaria has been reached in the brickyards at Brentwood Railway Station, and above it the loams (2-5 of the section at p. 274) are worked. These same beds have been dug in other places, and they spread out beyond Westbury Cottage toward Brook Street, being shown in a pit a little north of the seventeenth milestone. In the railway-cutting at Thrift Wood they again appear, and they take up a good deal of ground north of Thorndon Hall and in Thorndon Park, east of Belcher's Hall."

"At Galleywood, Billericay, Blackmore, and Stock the junction-beds with the Bagshot Sand (sand, loam and clay) are worked. The clay is worked near Bridge Farm (north of Hutton) at Ingatestone, Ramsden, and Rettenden Commons and at Maldon. It has the ordinary features, and septaria are generally present."

MR. BRISTOW notes that "at Barrack Lane (Chelmsford) pits have been dug 16 feet in the clay, which contains small concretionary lumps of marl."

MR. F. CHALLIS says the clay "is worked at Broomfield [N. of Chelmsford] and Widford [S.W. of Chelmsford] for drain-pipe and brick-making. At Widford it abounds with crystals of selenite . . . Among the organic remains found are sharks' teeth and the vertebrae of fish, crustacea, a large *Nautilus*, and two species of *Fusus*. Stems of plants and wood bored by *Teredo* are not uncommon . . . The fossils at Broomfield are nearly identical

\* *Essex Naturalist*, No. 9, p. 186. (1887.)

with those found at Widford. The so-called "coprolites" abound.\* In an earlier note he remarks that some of the Widford Crustacea are in a good state of preservation.†

In the summer of 1887 I spent some days in the examination of the railways then in progress in that part of Essex now described, chiefly along the line from Shenfield to Southend. Most of the cuttings on this line show the London Clay, and many nothing else. The peculiarity of the formation throughout is the apparent absence of fossils, though probably a more diligent search than could be made in my quick passage might yield some result. The discoloration of the clay, from grey to brown, by oxidation, was mostly well-shown. Such of the cuttings as fall within this section of the Memoir will now be noticed, going from the west eastward; but parts of the work had not been begun at the time of my visit, so that some cuttings are without notice.

The cutting south-westward of Mountnessing Hall showed brown London Clay, with septaria, without any capping of Drift, except just at the middle part, where, east of the wood, there is at top a little brown stony clay, probably the weathered end of the patch of Boulder Clay to the south, which therefore would seem to have been originally taken too far east on the map.

The cutting northward of Great Cowbridge Grange, W.N.W. of Billericay, must have given a good section of something, but of what cannot be said, the sides being overgrown at the time of my visit. A damp-line rises up, irregularly parallel with the surface of the ground, possibly from the occurrence of a sandy bed in the London Clay.

The great cutting at Billericay showed the uppermost beds of the formation (see p. 277), and it is noteworthy that the most sandy beds did not occur at the top, but lower down, at the western part of the cutting.

A little eastward, from the road E.S.E. of the Union, the short cutting showed brown clay, grey and sandy below, the beds rising slightly east, so that the hill is in a slight hollow, as in the great cutting they rise westward.

The next cutting to the east may prove to be in the passage-beds up into the Bagshot Sand (see p. 278).

The cutting that begins about three quarters of a mile eastward of Billericay Station is nearly divided by a hollow, with washed earth in it. The western part is in brown bedded clay, with sandy layers, and a bed of sand in the lower part, the beds rising slightly eastward. The eastern part is also in bedded clay, of like character, grey at the base, nearly flat, but showing a gentle wave on the east.

Through the woods eastward there are three cuttings in brown clay, with septaria, the lowest part grey in the easterly two; and in the next wood is another cutting, in part of which, just beyond the wood, a capping of Drift occurs (see p. 326).

Along Kent Hill and Pump Hill (Ramsden Bellhouse), just north of the railway, the comparatively sharp southerly slope of the ground has resulted in landslips, the clay not being able to stand at a high angle. At the foot of the former hill there is a small cutting in brown clay.

The cutting south of Downham Church is through brown and grey clay, with septaria, and with some stony patches at top.

In the next cutting eastward the clay was brown (or discoloured throughout) and also with septaria.

The next, N.W. of Wickford Station, showed some gravelly patches and loam over the brown clay.

For some way south-eastward of this the cuttings were not made.

Near Rayleigh there are several cuttings in this formation.

\* *Essex Naturalist*, No. 1, p. 16. (1887.)

† *Science Gossip*, March 1885, p. 68.

That northward of Great Wheatley is in brown clay with septaria, and clay was also shown on either side of Rayleigh Station.

Southward of Down Hall a deeper cutting, probably reaching up to higher beds, is through brown clay, with two beds of sandy clay, marked by damp, and showing a slight inward dip, from either end.

N.E. of Down Hall is another cutting in brown clay, sandy at the base.

On the road-cutting, under the line, N.N.E., brown clay was again shown, and the cutting just beyond gave a good section of some of the sandy upper beds of the London Clay, the succession being as follows, though some points could not be clearly made out, because of the section being partly hidden; on the south-eastern, or higher, side drains had been cut up the slope to about the base of the sand :—

Brown clay, at the highest part.

Brown sandy clay;  $\frac{1}{2}$  3 to 4 feet.

Fine soft brownish sand, with thin layers of clay; a few feet ( $\frac{1}{2}$  3 to 4).

Brown sandy clay, damp;  $\frac{1}{2}$  thick.

Grey clay at the base.

The cutting through Blounts Wood, and about a third of a mile N.W. of Hockley House, showed brown bedded clay, rising slightly east, and some of the beds being rather sandy.

At Blounts, a third of a mile north of Hockley House, there is a tiny cutting in brown clay, rather sandy at the base, just north of the house; whilst just south is a pit in brown loam. This latter was originally included within the line of the Bagshot Sand; but I should decidedly class it as London Clay.

In the road-cutting under the railway south of St. Peter's Church and Hockley Hall brown clay was shown, and the cutting just E. at first passes through bedded light-brown sandy clay, with clayey sand and some buff sand, the inward dip (E.) being rather sharp. This cutting was unfinished, and apparently would be deeper beyond: it continues (so far as could be seen) in bedded clay, with a small pipe of gravel on the northern side (S.E. of the the church), where the beds are flat, but further on they rise eastward.

The cutting westward from Hockley Station to Marylands Wood is in clay, with septaria; the upper part weathered brown, parallel to the surface of the ground, the base, at the deepest part, being grey. At the eastern part the beds rise slightly eastward.

The cutting eastward of Hockley Station was much hidden, in August 1887; but is in brown clay, with septaria. There is a damp zone about half way down, pointing to the existence of a sandy bed, and before reaching the bridge over the line, another like zone sets in, at or near the base. At the bridge there is brown loam, and, a little further, the now shallow cutting ends in brown stony sand. It looks therefore as if there were a little Drift at the eastern end.

Mr. BRISTOW has noted that "there is a spring at Hockley, the water of which, like much of that in the London Clay, contains sulphate of magnesia (Epsom Salt). An endeavour was made some years ago to establish a 'Spa' with 'pump-rooms,' and a woman was employed to dispense them, whose strong healthy appearance visitors were led to believe was the result of the medicinal effects of the water. In spite however of such a strong corroboration of the efficacy of the Hockley waters the public refused to be cured and the speculation proved a failure; all that now remains of the Spa being the buildings which are still known as 'Hockley Spa.'"

"Sulphate of magnesia is also present in other water from the London Clay of this district. The farmer at Plumberrow Hall told me that his sheep, on being freshly brought to the farm from some other part of the country, were violently affected (scoured) by the change of water; but that after a while the unpleasant effects of the water wore off and the sheep looked in better condition than at first."

A small outlier of Bagshot Sand was originally shown on the map, on the higher ground from Hockley Wood to north of Hawkwell Common. The beds shown however at the abandoned brickyard at its western end, south of the Royal Oak Inn, are brown clay on the north, and on the south, a trifle

higher, brown loam and sand, all of which I should class with the upper sandy part of the London Clay.

Turning to the railway from Wickford to Maldon, the most southerly cutting seen was that southward of Stow Maries, which showed both brown (=discoloured) and grey London Clay, with some wee pockets of gravel on the north; and the brown clay was also seen in the road-cutting under the line eastward.

At Cold Norton the long and fairly deep cutting (chiefly southward of the station) showed nothing but brown London Clay, with septaria.

In the cutting north-eastward of Purleigh there is again brown clay, but capped by Drift on the south (see p. 327). The road-cutting under the line, to the south, was also in brown clay.

The railway-cutting a third of a mile east of Hazeleigh Church and Hall gave a shallow section of brown clay, and the like was seen southward, in ditches across the line, in one of which however, south-eastward of the church, there was a capping of clay with gravelly patches (alluvial).

The Maldon cutting will be described further on, p. 316.

The following notes, of the slopes and cliffs bordering the Thames near Southend, are by MR. BRISTOW :—

“Fragments of septaria are ploughed up in the fields north of Hole Farm, between South Benfleet and Hadleigh, which are on stiff brown clay.”

“The cliffs between Leigh railway-station and the Crow Stone are of dark brown clay with a few septaria. The face is very uneven through slips.”

“Eastward the lower part of the cliffs consists of blue clay with layers of irregularly-shaped septarian nodules, which may be seen in place and strewing the shore, and which have been used for making the sloping sea-wall. The upper part consists of brown clay.”

“Where the New or Cliff Town of Southend is built, west of the old town, the cliff is steep, tumbled, and overgrown in places; the lower part consisting of brown clay with occasional layers of septarian nodules, and the highest part of gravel.”

### FOSSILS.

It seems needless to give a list of the fossils of the London Clay of our district, apart from those of eastern and western tracts, and, for a general list, the reader is therefore referred to the Memoir on the London Basin,\* whilst a much newer special one, for part of the neighbourhood of London, will be found in MR. J. L. LOBLEY's paper on “the Geology of the Parish of Hampstead,”† in which the names are given under five headings :—the Upper Sandy Clay, the Main Bed of Clay, Haverstock Hill, Primrose Hill, Basement Bed, besides a few under the general heading Hampstead.

MESSRS. C. D. SHERBORN and F. CHAPMAN have given a long list of *Foraminifera* (including some new species) and a shorter one of *Entomostraca*, with descriptions in the former case, from drainage-works in Piccadilly.‡

Another group of microscopic organisms has also been lately found to occur in the London Clay. In describing a well at Sheerness (just beyond our district) Mr. W. H. SHRUBSOLE noticed that “at and below 293 feet the clay was studded with very minute discs of iron pyrites, each having a boss in the centre,

\* Geological Survey Memoirs, vol. iv. pp. 587-599. (1872.)

† *Middlesex Nat. Hist. Soc.*, pp. 87-98. (1887.)

‡ *Journ. R. Micr. Soc.*, ser. ii., vol. vi., pls. xiv.-xvi. (1886.)

and the edge slightly turned up all round. They were uniformly perfect [this should have been "perfectly uniform"], as much so as if cast in one mould.\*

It was not however until some time after that he found out that these were mineralized Diatoms, and that they occurred in specimens from two other wells at Sheerness. "Finding them thus in three wells some distance apart, I suspected that, although limited to one zone, there was probably a considerable lateral extension of the diatomaceous band," and he succeeded in finding specimens, eastward, beyond Herne Bay and south-westward, at Upnor (both beyond our bounds), "of the same species, in the same condition, and at the same geological level" near the base of the clay. He goes on to say, "I went next to the Loam Pit [Hill] brickyard at Lewisham, and was rewarded with equal success" . . .

"In a well in progress at Prittlewell for increasing the water supply of Southend, no diatoms were found until the depth of 360 feet from the surface . . . was reached."

"From various considerations . . . there is little doubt that these diatoms existed continuously throughout the London clay period. Yet . . . no trace of them is found except as having existed in the early part of that period."†

MR. F. KITTON adds some "Remarks . . . with a List of the Genera," which includes 25 specific determinations.

Of other fossils it is enough to note that fish-remains, referred to 7 genera, have been found; that Cephalopods are represented, chiefly by 6 species of *Nautilus*; that very many genera of Gastropods occur, *Cassidaria*, *Cypræa*, *Dentalium*, *Murex*, *Natica*, *Pyrula* and *Voluta* having 3 or more species, whilst *Fusus* has many more and *Pleurotoma* far exceeds this; that of Bivalves also many genera occur, the following with 3 or more species, *Avicula*, *Cardium*, *Corbula*, *Leda*, *Modiola*, *Nucula*, *Pinna* and *Verticordia*; that Crustacea and Annelids are fairly represented; and that Echinoderms and Corals also occur.

With the basement-bed however the case is somewhat different. Our district contains many of the most fossiliferous localities, and the lists from these are therefore reprinted, with some additions, from Memoirs, vol. iv., the localities being marked by numbers, as follows:—

1. *Lane End.* } PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. vi. p. 267,
2. *Bray Cut.* } with additions.
3. *Hedgerley.* PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. vi. p. 268.
4. *Cowcroft.* Near Chesham. Half from PROF. PRESTWICH. *Quart. Journ. Geol. Soc.*, vol. vi. p. 268, and half from specimens got by myself.

\* *Proc. Geol. Assoc.*, vol. v., no. 7, p. 357, dated 1878, but not published until 1879.

† *Journ. Roy. Micr. Soc.*, ser. ii., vol. i., pl. v.

5. *Batchworth Heath.* } From specimens got by DR. J. EVANS and by myself,  
 6. *Bennet's End.* } in great part named by MR. R. ETHERIDGE.  
 7. *Bushey.* PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. vi. p. 269.  
 8. *Watford Heath.* From specimens got by myself, with additions from  
 MR. J. HOPKINSON, *Proc. Geol. Assoc.*, vol. ii., no. 2, p. 43 (1871).  
 9. *Hampstead.* (Well.) MR. N. T. WETHERELL, *Trans. Geol. Soc.*, ser. 2,  
 vol. v. p. 133. See also PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*,  
 vol. vi. p. 261.

## MAMMALS.

<i>Hyracotherium leporinum</i> , Owen	-	-	-	-	-	-	-	-	8
Bone	-	-	-	-	-	-	-	-	6

## REPTILES.

Turtle-bones	-	-	-	-	-	-	-	-	8
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## FISH.

<i>Lamna</i> , teeth	-	-	-	-	1	2	3	4	5	6	-	8
<i>Otodus</i> , teeth	-	-	-	-	-	-	-	-	-	5	-	8
Bones, scales, teeth, vertebrae	-	-	-	-	-	-	2	3	-	-	-	9

## MOLLUSCA.

*Gasteropoda.*

<i>Aporrhais Sowerbyi</i> , Mant.	-	-	1	2	3	-	-	-	7	8	9
<i>Calyptræa trochiformis</i> , Lam.	-	-	1	2	-	-	-	-	-	-	-
<i>Cassidaria nodosa</i> , Brand.	-	-	1	-	-	-	-	-	5	-	-
„ <i>ambigua</i> , Sol. (= <i>striata</i> , Sby.)	-	-	-	-	3	-	-	-	-	-	-
„ sp.	-	-	-	2	-	-	-	-	-	-	-
<i>Fusus</i>	-	-	1	2	3	4	5	6	-	-	-
<i>Natica hantoniensis</i> , Sby.	-	-	-	-	3	-	-	-	-	-	-
„ <i>labellata</i> , Lam.	-	-	1	2?	3	4	-	-	-	8	9
„ sp.	-	-	1	-	-	-	5	6	-	-	-
<i>Pleurotoma</i>	-	-	-	-	3	-	5	-	-	-	9
<i>Pyrula Smithii</i> , Sby.	-	-	1	2	-	-	-	-	-	-	-
„ <i>tricostata</i> , Desh.	-	-	-	-	3	-	-	-	-	-	-
<i>Scalaria</i>	-	-	-	-	3	-	-	-	-	-	-

*Lamellibranchiata.*

<i>Cardium Laytoni</i> , Mor.	-	-	1	2	-	-	5	6	-	-	9
„ <i>nitens</i> , Sby.	-	-	1	2	3	-	-	-	7	-	9
„ <i>plumsteadiense</i> , Sby.	-	-	2	3	-	-	5	6?	7	-	-
„ sp.	-	-	1	-	3	-	-	-	7	-	-
<i>Corbula regulbiensis</i> , Mor. (first given as C. <i>revoluta</i> )	-	-	-	-	3	-	-	-	-	-	-
<i>Cyprina Morrisii</i> , Sby.	-	-	1?	-	-	-	5	6	-	8	-
„ or <i>Cytherea</i>	-	-	-	2	-	-	-	-	-	-	-
<i>Cyrena cuneiformis</i> , Fer.	-	-	-	2	-	-	-	-	-	8	-
<i>Cytherea obliqua</i> , Desh.	-	-	1	2?	3	4?	-	6	7	8	9
„ <i>orbicularis</i> , Edw. (taken for C. <i>bellovacina</i> , Desh.)	-	-	-	2	-	-	5	6	-	-	-
„ <i>ovalis</i> , Sby. var. (? = C. <i>orbicu-</i> laris)	-	-	-	-	3	-	-	-	-	7	-
<i>Glycimeris</i> ?	-	-	-	-	3	-	-	-	-	-	-
<i>Lithodomus</i> ? (bores)	-	-	-	-	3	-	-	-	-	-	-
<i>Modiola depressa</i> , Sby.	-	-	-	2	-	-	-	-	-	-	-
„ <i>elegans</i> , Sby.	-	-	1?	2	3	-	-	-	-	-	-
<i>Nucula</i>	-	-	-	2	3	-	-	6	7	8	9

<i>Ostrea bellovacina</i> , Lam. (including <i>O.</i> <i>edulina</i> , Sby.) -	-	-	-	2	-	4	-	6	-	8
„ <i>pulchra</i> , Sby. from Chesham (S. V. Wood) sp.	-	-	1	2	3	-	5			
<i>Panopæa granulata</i> , Mor.?	-	-	-	-	-	-	5			
„ <i>intermedia</i> , Sby.	-	-	1	2	3	-	5	6	7	8 9
<i>Pecten</i> -	-	-	-	2						
<i>Pectunculus brevirostris</i> , Sby.	-	-	1							
„ <i>plumsteadiensis</i> , Sby.	-	-	1	2	3	-	5	6?		
<i>Tellina?</i> -	-	-	1	2	3	-	5			
<i>Brachiopod.</i> <i>Lingula tenuis</i> , Sby.	-	-	1							
ANNELID. <i>Ditrupa plana</i> , Sby.	-	-	1	2	3	4	-	6		

## PLANTS.

Leaves, impressions of	-	-	-	-	-	-	-	6		
Lignite	-	-	-	-	-	-	-	-	7	
Wood	-	-	-	-	2	3	-	5	6	



## CHAPTER 17. LOWER BAGSHOT BEDS.

## GENERAL REMARKS.

We have here to deal only with outliers of the lower division of the great Bagshot Series, and this is very satisfactory! Years after the publication of the Memoir in which the whole of this Series, in the London Basin, was described,\* a controversy arose, not only as to the relation of the Bagshot Beds to the underlying London Clay, but also as to the behaviour of its divisions to each other. As that controversy can hardly be said to have ended, and as there is a possibility of other fresh views arising, it is a source of much thankfulness to the writer to be spared, for the present at all events, from entering into the field.

The outliers in our district consist of fine sand, mostly light-coloured, but sometimes iron-stained, and even cemented into iron-sandstone (though not in large masses); sometimes too there are thin layers of clay in the sand, and the lower part is generally loamy, showing a passage into the sandy clay beneath (see pp. 239 &c.) Above the sand there is very generally, in Essex, a deposit of flint-pebbles in a sandy matrix, and in that county the sand is for the most part thinner than to the west. The pebble-bed is of the same character as that of Blackheath, &c., below the London Clay: indeed an observer would not know but what he was on that lower formation were it not for the fact that the lower ground around him consists of London Clay, instead of hills above him being formed thereof.

A marked feature of the whole is its being practically unfossiliferous. Near Egham, labourers "have occasionally found specimens," which are presumed "from their description to be casts of shells,"† and many years ago, my friend MR. R. B. FOOTE, of the Indian Geological Survey, gave me a piece of the cast of a whorled univalve (*Turritella*?) that he had found in a ferruginous concretion at Hampstead.

The above were the only recorded instances of fossils from these sands, in the London Basin, until, whilst this Memoir was passing through the press, MR. H. W. MONCKTON and MR. R. S. HERRIES succeeded in finding some casts of shells in sand, at Mill Green, north of Frierning, in Essex. These casts, which are ferruginous and fragile, belong apparently to the genera *Turritella*, *Natica* and *Voluta*. I am indebted to MR. MONCKTON for speedy news of the find and for permission to notice it here (see also p. 276).

All the Bagshot Beds of our district are here classed as Lower Bagshot, because that is the classification of the Geological Survey Maps, which were made long ago, before the controversy alluded to had arisen (and which moreover has hardly been carried into

\* The Geology of the London Basin . . . *Geol. Survey Mem.*, vol. iv. (1872.)

† PRESTWICH. *Quart. Journ. Geol. Soc.*, vol. iii. p. 389.

our district). It is of course for the advocates of a new reading to prove their case, and that has certainly not been done for the area with which we are concerned.

It is possible that some of our sands and pebble-beds may be claimed as Middle or as Upper Bagshot; but the question of classification can make no difference to the mapping, which is merely a representation of facts:—the sands overlie the London Clay and are overlain by the pebble-beds, as shown on the maps, whatever anyone chooses to call them! As however we find a passage from the London Clay up into the sand, often indeed spread over a great vertical range of beds, and as we have no proof of unconformity (which would be likely if there were a gap in the series) one may, it is to be hoped, still adhere to the name Lower Bagshot for the beds to be described, without laying oneself open to severe criticism.

#### MIDDLESEX.

In Middlesex there are outliers, forming the tops of Harrow, Hampstead, and Highgate Hills, each of which is a marked feature of the landscape, those hills being indeed the most conspicuous objects in the county, from their isolation, though the London Clay ridge, with its capping of pebbly gravel, at Stanmore Heath, is higher.

##### *Harrow.*

The occurrence of the Bagshot Sand here shows that the London Clay is thinner than one might expect; for at the Waterworks there is a thickness of but 110 feet of the latter, at a level only 180 feet below the church (*see* Well-sections, *post*).

In the earlier issues of the Map (Sheet 7) one larger mass was shown, but with the newer six-inch maps MR. BRISTOW was able to define the sand more clearly, as he describes below.

"The uppermost beds of the London Clay are often to be seen, owing to the road-cuttings and to the many openings made for the foundations of houses. Above these loamy beds there seems to be here and there light-coloured sand with a little pipe-clay, forming the highest parts of the hill. The old church, which is a well-known land-mark, stands on the most northerly, and probably the thickest mass. There is a larger but more doubtful outlier about half a mile south of the church, barely separated from the third and smallest patch, to the west. The mapping of all three was made difficult and vague from the absence of sections, the enclosed nature of the ground, and the gradual passage upwards of the London Clay into the sand."

"Lying about there are pieces, and sometimes large blocks, of ferruginous grit, with flint-pebbles."

Unfortunately one must depose the Harrow outlier from the high position given to it by Mr. J. L. LOBLEY, as "the most northern patch of these sands in existence, not only in England, but in the world;"\* for much of the Bagshot Sand in Essex is further north than Harrow.

##### *Hampstead.*

The largest and best marked of the Middlesex outliers forms all the highest ground of Hampstead and gives rise to the well-

\* *Trans. Watford Nat. Hist. Soc.*, vol. i., pt. ix., p. lviii. (1878.)

known gorse-covered heath. The irregularly-winding boundary of the sand is well-marked on the whole, both by the sharp rise of the ground and by the water thrown out from these permeable beds by the underlying water-tight London Clay.

The sand spreads from the western end of the kitchen-garden at Kenwood, on the road to Highgate, westward nearly to the high road at Child's Hill and southward to Rosslyn House; the northern end of the outlier, in Bishop's Wood, is rather hidden.

There were many pits on the Heath, and they showed light-coloured sand, with thin layers of clay here and there: so much indeed has the sand been dug away that but little of the original surface of the ground has been left.

The cutting of the road down to North End gives a good section of the sand; and on the south-west of that place there is a bay of London Clay, the Bagshot Sand having been denuded away along the hollow, broad to the N.W., but narrowing towards the flagstaff on the top of the hill. On all sides of this bay much water is thrown out from the lower part of the sands, and this, running over the clay below, formed a regular and constant swamp, in wet weather impassable at most parts and not to be ventured on carelessly at any time, making a most delightful skirmishing-ground for volunteers, as the writer himself can bear witness. I believe however that this has lately been improved (?). South of this sand is often shown along the roads.

At the lower part of the old churchyard the brown sandy clay, that here forms the uppermost part of the London Clay, is found; showing that the Bagshot Sand must come on close above.

In the field just west of Rosslyn House the junction of the two formations is well marked by an ever-flowing spring of very clear water. Just north of the house the sand is shown; and a little further north, in the cutting for a road down the slope towards the high road, I saw the following beds, in descending order:—sand, clayey sand, sandy clay and clay; the first two belonging to the Bagshot Beds, the others (which were also shown at the brickyard) to the London Clay, and the whole showing a passage between those formations.

The cuttings made for the branch of the Northern High Level Sewer through Hampstead gave many good and deep sections of the sand, and, at the lower part of the town, of its passage into the London Clay. At one place there was light-brown sand capped by light-green sand, which latter Mr. BRISTOW, who saw the section with me, thought might belong to the Bracklesham Beds (Middle Bagshot): this does not however spread over the whole top of the hill, but seems merely to be a small patch in a hollow on its southern flank; and I think that there is hardly evidence to warrant one in separating this green sand from the Lower Bagshot Beds on the Geological Survey Map, more especially as I afterwards saw some bluish-green clayey sand lying at once on the London Clay in Well Walk, on the south of the Vale of Health.

MR. C. EVANS told me, in 1871, that "the line of sewer across the Heath, from Well Walk to the Vale of Health, passed through green clayey sand; the excavations being about 20 feet deep, and carried to a lower level than the pond. A like bed was seen at the top of Rosslyn Hill in a side-drain to the Scotch church."

The water of the large pond at the Vale of Health is held up by the London Clay, whilst on all sides, except to the east, there is sand.

N.E. of this an irregular-shaped spur of the Bagshot Beds stretches for some way into Kenwood Park, sand being shown in places.

In the farmyard of the park, nearly opposite The Spaniards, there is a sand-pit; but from this part to the house the boundary-line is by no means the clearer for the artificial changes of the surface of the ground.

The thickness of this formation at Hampstead may be from 60 to 80 feet.

#### *Highgate.*

This hill is a few feet lower than that of Hampstead, and the capping of the Bagshot Beds is neither so thick nor so wide-

spread. Sand is not dug here, and therefore there have been but few sections: nevertheless the boundary-line, less winding than that of the Hampstead outlier, is for the most part well-marked. The outlier spreads from a little north of The Wrestlers Inn southward to the higher part of the Cemetery and then eastward a little beyond the Archway.

In Southwood Lane, on the northern slope of the hill, there are constant springs, supplying the cottages near by; indeed water is easily got at most parts of the outlier.

On the southern slope of the hill sand is shown in the lanes on either side of the Cemetery, and in Maiden Lane, just below the junction with the high road.

The deep cutting of the Archway Road goes down some depth into the London Clay; so that a small part of the outlier has been artificially cut off from the rest. On the north of the Archway the higher part of the cutting shows sand above sandy clay, and on the south the former may be better seen at the back of some houses on the eastern side of the road.

In the cutting for a road, running north-eastward from High Street, and N.W. of Cromwell House, much coarse iron-sandstone has been found in the Bagshot Sand. Most of the many blocks lying about contained flint-pebbles. MR. JUKES-BROWNE tells me that he has seen like iron-sandstone dug in graves at the highest part of the Cemetery.

In 1883 MR. C. REID took me to some new sections, laid open along a new road and in excavations for the foundations of houses, close to Cromwell House (to the N. and N.E.). These showed a pebbly wash over a ferruginous grit (? false-bedded), with flint-pebbles (some rather large) and sand, at one part underlain by sand which was loamy at top. MR. REID tells me that he has seen other like sections near by.

As pebbles were also seen in an excavation in the High Street, south of the Grammar School, there may be a trace of the pebble-beds here.

There may be a small thin capping of sand on the top of Parliament Hill, between Hampstead Heath and Kentish Town.

## SURREY.

At the top of Kingston Hill there is an outlier of Lower Bagshot Sand. It is but a thin capping, and is almost wholly hidden by the gravel that covers the top of the hill; so that its boundary, with the exception of the western part, is very doubtful. Along a road on the west of the turnpike-road a little above Norbiton Pottery, where the London Clay is sandy and seems to show an upward passage into the Bagshot Sand (see p. 241), a thickness of some feet of fine light-coloured and rather clayey sand was to be seen (in 1860), not like the coarse gritty sand that occurs in the gravel, but quite free from any mixture of gravel.

At an old pit at Thatched House Lodge, there is fine light-coloured sand beneath the gravel, and unlike the coarse sand that occurs in the latter. The boundary of the outlier is made very doubtful by the gravel which everywhere caps the hill, and at first I mapped too large an area as Bagshot Sand, an error that has been corrected in mapping the gravel (on the 6-inch scale).

The outlier on the top of the Ridgeway, Wimbledon, has a like doubtful boundary, and from the same cause, the bed of gravel that caps the hill. As on Kingston Hill, the London Clay is very sandy toward the top; and here it shows clear signs of passing upward into the Bagshot Sand (see p. 241). In digging for the foundations of some houses a little south of the road, and about three quarters of a mile south of west of Wimbledon Railway Station, fine whitish and rather clayey sand was found beneath the gravel.

## ESSEX.

*General Account.*

When the Geological Survey of South Essex was made we did not recognize as belonging to the Bagshot Series the pebble-beds that had been classed with it by MR. S. V. WOOD, JUN.,\* and our earlier maps were issued without those beds being marked on them. Fresh evidence however, not only in the fact of these pebble-beds being seen to dovetail into the sand in some of the Essex outliers, but also from like deposits being found in the main Bagshot tract,† led to the acceptance of MR. WOOD's views.

In the re-survey of South Essex thus made needful, and which was chiefly done by MR. H. B. WOODWARD, a great many additions were made to our maps, besides many important corrections. The following description is indeed to a very great extent by my colleague; but before proceeding with it I must pay a tribute to the never-failing frankness of MR. WOOD, who was always ready to give all the information in his power to other geologists, as witness the valuable MS. Maps and Memoir that he placed in the library of the Geological Society.

The following general remarks are by MR. WOODWARD.

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From the Bagshot Beds themselves varying so much in character, and from the passage upward of the London Clay into them, it is impossible to be certain of the horizon which should be taken as the junction of the two formations in the many outliers of Essex. Whilst a purely sandy condition prevailed at one spot, a loam may have been formed at another, and a clay at a third. Again the test of level avails but little when it is remembered to what changes the area has been subjected in later times, during and after the Glacial Period: nor is it likely that the beds were spread over a uniform level; so that, taking these points into consideration, it seems that the boundary between the Bagshot Beds and the London Clay must be drawn mainly with reference to the features of each outlier.

Probably the best place for studying the Bagshot Beds in Essex is Brentwood, where the structure of both the sands and the pebble-beds, and also their relation to the London Clay, are clearly shown. In the sections there the London Clay is seen to pass upward into the Bagshot Sand. The brickyards well show the passage-beds, which consist of alternations of clays, sands and loams, furnishing excellent brick-earths. The passage makes the boundary-line between the two deposits very indefinite, and that line is liable to be taken at different horizons in different localities, even in the same outlier. There is no marked plane of separa-

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\* *Ann. Nat. Hist.*, ser. 3, vol. xiii. p. 197. (1864.) *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 464. (1868.)

† See *Geological Survey Memoirs*, vol. iv. p. 315. (1872.)

tion, and it therefore becomes a matter of convenience where to draw the boundary. MR. WOOD has treated all the beds above the stiff London Clay as Bagshot Beds; but in mapping the outliers around Brentwood, a higher boundary has proved to be the most marked one, for the most marked change in the form of the ground occurs there.

That the pebble-beds (overlying the sand) are distinct from the pebble-gravel of Hertfordshire, &c., has been pointed out by MR. WOOD,\* and it is apparent to any one familiar with the two deposits. The absence of quartz-pebbles is a marked feature in connection with these pebble-beds, and is alone sufficient to distinguish them from the pebble-gravel. Their position, and the occurrence in them of sand and pipe-clay of Bagshot character, justify us in assigning them to that period.

MR. WOOD notices the greatest thickness of these beds as nearly 20 feet at Warley, and mentions that at times they rest "somewhat unconformably upon the Bagshot Sand." That they rest occasionally in basins or hollows in the sand appears evident when they are traced out, but this irregularity may rather be attributed to the mode of deposition, than to any unconformity indicating lapse of time between the formation of the sand and of the pebble-beds. He maintains "that the pebble-beds referred by him to the Bagshot Series, when truly *in situ*, are free from quartzite." The beds however having been covered by Drift during the Glacial Period, have necessarily been disturbed at their surface, and thus foreign fragments have been occasionally introduced.

In a letter from MR. WOOD (1872), the following remark occurs:—"I still think that the question whether the pebble-beds may not belong to some older Pliocene sea (as discussed at p. 465 of my paper) is open to argument, there being no palæontological evidence whatever," and some years later he leaned more to this view, saying that the pebble-beds "are either of Bagshot, or, more probably, of Diestian age."†

The beds appear to thin out in a north-easterly direction, and at Galleywood and Norton Heath the pebble-beds seem to rest directly on the London Clay, or with merely a trace of sand beneath them; but whether these are the true Bagshot pebble-beds was regarded as doubtful by MR. WOOD. It follows therefore that the north-eastern outliers cannot readily be correlated with those of Brentwood. They consist generally of sand with an overlying bed of brick-earth, possibly identical with the lowest beds at Brentwood. As these however are liable to much variation no definite opinion can be expressed.

H. B. W.

### *Between the Lea and the Roding.*

#### *High Beech.*

This well-marked outlier is in great part capped by pebble-gravel, but the Bagshot pebble-bed does not occur.

\* *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 464, &c.

† *Ibid.*, vol. xxxvi. p. 473. (1880.)

On the northern side of the Common there are many springs, sometimes with a rich growth of *Sphagnum* and of other marsh-plants.

Some pits a little north-west of the King's Oak Inn, at most ten feet deep, showed light-brown and buff sand with thin layers of pale grey pipe-clay, in parts very thinly bedded, the layers of bedding being marked by the alternation of light-coloured and dark grains in the sand.

A good section was laid open in 1887, in the excavation for the reservoir of the East London Water Company, a little south-westward of The King's Oak Inn, and an account of it was published by MR. T. V. HOLMES.\* In the following description that account has been used, as well as a note sent me by MR. H. B. WOODWARD, made at the same time, together with my own notes, made a little later.

Sandy and gravelly soil, up to a foot thick.

Clay or loam, with pebbles. At one part (N.) this was more stony at the base and rested on the Bagshot Sand, which rose up sharply from beneath westward. Eastward this clay had few stones and went down to the base of the pit (? decomposed Boulder Clay).

Irregular pebbly gravel, with a clayey matrix, resting unevenly on the sand below, and mostly without clay above. "The pebbles were chiefly of flint (from half an inch to 4 inches in length), but a few were of quartz and many had the longer axis vertical. Some broken flints occurred, in coarse brown sand and grey clay" (Woodward).

Bagshot Sand, fine, light-coloured and yellowish, with occasional thin layers of pipe-clay; one of these, low down, seemed constant, was up to 10 inches thick, and at one part (N.W.) split into two layers, with sand between. Up to 8 feet seen, the sand rising to within 2 feet of the surface at the southern end.

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There may be some Bagshot Sand east of Epping, but the ground is much covered by pebble-gravel. MR. H. B. WOODWARD notes that "at Cooper-sale Common a little yellowish sand is shown by the roadside, and in the railway-cutting north of Ongar Lodge sand and loam may be seen; but over the greater part of Ongar Park Wood there is stiff loam, like the top part of the London Clay; the level too is lower than at Epping Plain, where there is no true Bagshot Sand, but only the sandy passage-beds of the London Clay; and consequently the large outlier first mapped here has been expunged, except more than half-a-mile northward of Theydon Mount Church, where there may be seen, in a brickyard, about ten feet of fine soft sand with layers of pipe-clay."

#### *Between the Roding and the Wid.*

"Just north of Chigwell Row there is some high ground on which there may be some Bagshot Sand, but the covering of Boulder Clay makes it uncertain." (F. J. BENNETT.)

A patch of sand caps the hill south of Lambourn, for rather more than a mile from north to south, from Bishop's Hall to Crabtree Hill, but is only about a quarter of a mile broad. "The only sections were just south of Forest Gate, where some holes, within a wood, showed about four feet of soft buff sand, covered at one place by two feet of brickearth. The northern part of the outlier is capped by a thin irregular deposit of pebble-gravel, with quartz-pebbles, and the boundary-line is hidden by Boulder Clay. (From MR. F. J. BENNETT's Notes.)

On the hill of Havering-atte-Bower an outlier reaches for half a mile both east and west of the church, and southward to Bedfords. "The pebble-beds cover nearly the whole of the northern part, and there was a pit in them east of Round House, whilst a little southward about five feet of sand were seen in a brickyard. The southern limb is covered by Boulder Clay" (F. J. BENNETT). MR. WOODWARD adds that "the western end is partly hidden by an irregular deposit of pebble-gravel, a wash of the pebble-beds."

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\* *Essex Naturalist*, no. 5, pp. 107, 108.

*Kelvedon Hatch.*

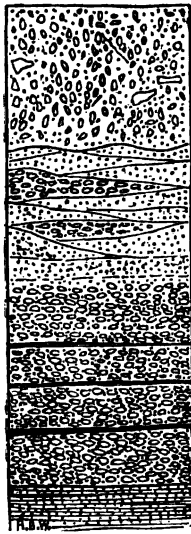
This large mass stretches from the south-eastern corner of Southweald Park over the high ground to nearly a mile northward of Doddington Church, with seven patches of the pebble-beds in the southern and central parts. The following description is by MR. WOODWARD.

In tracing the Bagshot Beds from near Brentwood to Kelvedon Hatch we find the Boulder Clay coming into contact with and often obscuring them. It has very frequently a loamy top and therefore there is often great difficulty in separating the two.

Buff sand is shown in pits by Half-way House, at the southern end of this large outlier, and there are also pits at Dudbrook on the north-west of Brycca.

MR. F. J. BENNETT notes that "in this outlier the sand seems mainly to be replaced by a brick-earth; there is however soft buff sand, about 5 feet deep, in a pit on Kelvedon Common."

At Langtons, South Weald Park, a large pit (for road-metal) gave the best section of the pebble-beds overlying the Bagshot Sand, and here it is that their position and age can best be determined, the beds shown being as in Fig. 46.



a. Figure 46. Section at Langtons, South Weald Park, near Brentwood.

(Scale 8 feet to an inch.)

- a. Pebbly gravel, chiefly flint-pebbles, with a few bits of quartz and some unworn flints. The pebbles mostly with the longer axis vertical. Up to 6 feet thick, but generally less.
- b. Pebble-bed, wholly of flint-pebbles about the size of plums (varying as much as that fruit), with fine soft sand in the upper part, where false-bedding is shown; but closely packed in the lower part, where beds of ironstone and layers of pipe-clay occur. Of a bluish-grey shingly appearance. About 15 feet.
- c. Loam, holding up water.

MR. S. V. WOOD, JUNR., kindly pointed out to me the general features of the pit before I visited it, and mentioned the distinct character of the top bed, which he regarded as a relic of Glacial times, and the possible equivalent of the pebble-gravel, or "Gravel of the Higher Plain" of PROF. HUGHES.\* This bed reminds me of the REV. O. FISHER's description of the "Trail,"† and seems to be the upper part of the pebble-bed, re-arranged in Glacial times, when foreign pebbles were introduced.

North of Langtons five patches of the pebble-beds may be traced, but none of great thickness (averaging about 2 feet). At Navestock Side 3 to 4 feet of

\* *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 283.

† *Ibid.*, vol. xxii. p. 558, and *Geol. Mag.*, vol. iv. p. 193 (1867).



the pebble-beds occur, as usual associated with loam and sand, and south-west of Bentley Mill are pockets of them.

Bordering the large mass are four small outliers of sand.

Near Kelvedon Hall two outliers have been mapped from the very sandy nature of the ground. They are on a slightly lower level than the main mass, and cannot have more than a couple of feet thickness of sand. Another small patch occurs westward of Stondon Grove, about a mile and a quarter southward of Stondon Massey.

At South Weald a few sections in the churchyard and another at the south-western corner of the outlier show the sand, but no traces of the pebble-bed occur on it.

Weald Park is covered with the lower beds of the Brentwood section (2-5, below), and perhaps also Rotchetts, where sand occurs to a depth of a few feet, and has been classed as Lower Bagshot, though its horizon is doubtful.

H. B. W.

#### *Brentwood and Warley.*

A large and rather straggling mass of the Bagshot Beds stretches southward from Shenfield, by Brentwood and Warley Common, to Warley Street and Ingrave, being artificially divided by the railway-cutting south of Brentwood. The description of this and the following outliers (to p. 279) is chiefly by MR. WOODWARD.

The general section at Brentwood may be taken as follows:—

	Pebbly gravel, etc.	
Bagshot Beds.	{ 8. Pebble-beds	- 15 feet
	{ 7. Brickearth or loam	} 25 "
	{ 6. Sand	
London Clay.	{ 5. Brickearth or loam	} 50 "
	{ 4. Clay	
	{ 3. Sand, 2 or 3 feet	
	{ 2. Brickearth or loam	
	{ 1. Clay, with septaria.	

As MR. WOOD has remarked the beds (2 to 7) appear to dovetail one into another, and to possess very little regularity when traced horizontally. He regards all the beds from 2 to 8 inclusive, as Bagshot, and he has coloured them as such in his Maps. This would give a thickness of nearly 100 feet to the Series.

PROF. W. B. DAWKINS, following MR. WOOD, took his line at the same point, but he did not include the brick-earths at the Station, although he included similar beds elsewhere in the same outlier.

In taking our boundary between 5 and 6, and regarding 6 to 8 as Bagshot Beds, and all below as London Clay, we have been mainly influenced by the desire to maintain consistency with work in other parts of the county, if possible. At this point moreover the most marked feature occurs, and the most copious springs are given out.

It is true that there is no decided line, marked by any peculiar band, or bed of fossils (none having been found in the Bagshot Beds of Essex at the time the Geological Survey was made); the form of the ground is indeed the main guide in tracing boundaries, for sections are by no means common, and thus it is often very difficult to decide whether or not some outlying hills may be Bagshot Sand, or may merely be capped by a lower bed of sand in the London Clay.

No. 6 is good sand, and is shown in pits around Brentwood, one of the best being just north-west of Thorndon Hall. In the railway-cutting, which is at one point 60 feet deep, the engineers having been prevented by the sand from

tunnelling, the junction is marked by a step; but unfortunately very little can now be seen, owing to slips and to vegetation.

Much of the ground at Warley is woodland, and there are few sections. The slope of the ground is sharp, so that there is but a small area of the Bag-shot Sand at Warley Gap, whereas towards Ingrave, where the slope of the ground is more gentle, a broader expanse of sand is the result.

MR. F. J. BENNETT notes that "at Galley Green, on the north, the Boulder Clay abuts against the sand, and at Brentwood the latter is widely capped by the pebble-beds, which conform pretty well to the contour, and may be seen on the Common. These last were also shown in a drain along the high road from Brentwood to Warley Street, near Warley Common."

The pebble-beds have been extensively dug on Warley Common, but as their average thickness cannot exceed 6 feet, from their having probably suffered from denudation, the pits are shallow and water is soon reached, when the brick-earth below is touched.

South of Warley House the pebble-beds increase in thickness, and indeed were worked to a depth of 12 feet in a pit north of Holdens Wood. Here, as elsewhere, they are capped by a bed of gravel containing pebbles of flint and of quartz.

Two outlying patches of the pebble-beds, not above 2 feet in thickness, occur between the Devil's Head and Thorndon Hall.

Eastward and southward of the outliers of the pebble-beds, a pebbly gravel has been formed by the wearing away of those beds, from Ellands Wood eastward to Belchers Hatch (see p. 295).

MR. BENNETT notes that "there is a small patch of the pebble-bed in the wood at Coombe Green."

At Ingrave there are traces of sand, but no good sections.

H. B. WOODWARD.

The following section is reproduced here, although (from the thickness of each bed not being given) it is hard to make out. MR. WOODWARD has however classified the beds as well as he could, though with some doubt, especially as to the "red gravel":—

Railway-cutting at Brentwood Hill, ? 60 feet deep.\*

	Mould.
? Bagshot Beds.	Loam.
	Dry sand.
	Sand with water.
? London Clay.	Loam.
	Loam and clay.
	Blowing sand.
	Red gravel.
	Blowing sand.
	Blue clay.

"On the western side of the Brentwood outlier, between Mascals and Warley Place, five very small patches have been mapped. There were no sections, but the sandy nature of the soil and the marked features served as guides." (From MR. F. J. BENNETT's Notes.)

Just south of the Brentwood outlier are two small patches of sand, near and west of Bellevue. Just east of Warley Street a mere dot of the sand is barely separated from the large outlier.

Continuing again MR. WOODWARD's description:—Traces of the pebble-beds occur at Norton Heath, resting on brick-earth, and very like the patch at Galleywood, where the former appear to overlap the sand, and to rest on a lower brick-earth.

\* P. BRUFF, *Proc. Inst. Civ. Eng.*, vol. iii. p. 161.

MR. W. H. PENNING who mapped this tract, which is surrounded by Boulder Clay, writes thus:—"There are several pits in Pre-Glacial flint pebble-gravel (over sand) in a whitish clayey matrix (? Bagshot Beds). This is a mass of gravel, sand and loam rising up through the Boulder Clay, and forming the higher ground. The like gravel, with an overlying patch of Boulder Clay, occurs in a pit S.E. of Witherspoons."

At High Ongar a sand-pit, about three quarters of a mile south of the church, is thus described by MR. PENNING, who mapped it as Glacial Sand. "15 or 16 feet of nearly white falsebedded sand, darker at bottom, and with occasional small patches of dark loamy sand; also a few flint and other pebbles, not all rolled (these last at the top)." This is regarded by MR. WOOD, as Bagshot Sand; but it is certainly at too low a level to be included with the Bagshot Beds as mapped by us, and as regards its position it looks most like Glacial Drift, and in this case it would be made up of Bagshot Sand.

#### *Frierning.*

This outlier, which reaches southward from this village to Trueloves, and northward to Portsmoor Hall and Parsons Spring Woods, where it is cut off by Boulder Clay, consists chiefly of sand, there being only three small patches of the pebble-beds. It was mapped by MR. WOODWARD who has written most of the following description.

Fine sand was very well shown at Mill Green Common and in Birch Spring Wood, but the surface over a great part of the area is loamy. The following section was noted at the former place in 1872:—

Glacial	{ Clay and loam.
Drift?	{ Gravel, 6 inches to a foot.
Bagshot	{ Yellowish sand, 6 inches.
Beds.	{ Loam.
	{ Whitish sand, 10 to 12 feet.

MR. H. W. MONCKTON contributes the following note of the small pit here (below the 300 feet contour-line, and about three quarters of a mile north of Frierning), in which fossils were got in 1888:—

Sand with a few pebbles.

Whitish clay; 1½ feet.

Nearly white micaceous sand, in one place near the top slightly false-bedded, otherwise with little sign of bedding. Ferruginous casts of fossils scattered throughout (see p. 266); 6½ feet seen.

In the brickyard, a mile south-east of Blackmore, brick-earth, sand, and clay are worked, the first (loam) occurring at the surface. Above it the pebble-bed may be traced in several places.

Frierning Church is on the pebble-beds, and they are also to be seen on Mill Green Common, and in Parsons Spring Wood.

At the last place pebble-beds, brick-earth and sand were exposed to the depth of 6 feet. Here I noticed in the surface-drift a few quartz-pebbles, and also a few comparatively unworn flints.

A few quartz-pebbles occur on Mill Green Common, and also broken pebbles; but the beds in place are composed of flint-pebbles. MR. S. V. WOOD, jun., noticed quartzite-pebbles in the pebble-beds near Frierning.\*

The Boulder Clay runs close up to this outlier, but in this, and in other similar cases, I doubt whether any of the Bagshot Sand is hidden.

South of Frierning no good sections are seen, but the surface of the ground is very sandy.

A small patch is but just separated from the above about half a mile north-west of Frierning Church.

Between Frierning and Ingatstone the Glacial Gravel is very pebbly, being largely derived from the Bagshot pebble-beds.

\* *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 464.

*Writtle Park.*

The most northerly mass of the Bagshot Beds yet mapped occurs about four miles south-west of Chelmsford and is thus described by MR. WOODWARD.

From Writtle Park Farm to Copfold Hall, there is sand, with a well-marked boundary, though rather obscure in places at the surface, on account of the usual brick-earth, that occurs between it and the pebble-beds.

A very good section of the sand, with seams of laminated clay, was seen about seven eighths of a mile S.E. of Highwood Church.

The pebble-beds were worked by the new Copfold Hall (not on the map), and they have been dug at Writtle Park Farm.

At Writtle Park Wood there is about 9 feet of pebbles and sand, and here I found one bit of quartzite, but this may have come out of the superficial loamy deposit. The pebbles otherwise were all of flint.

There is a loamy Post-Glacial gravel near Highwood, which lies on the Boulder Clay, and appears to be mainly derived from the Bagshot Beds.

*d. Between the Wid and the Crouch.**Billericay.*

MR. WOODWARD has supplied the description in the three following paragraphs:—

North-east of Billericay, the high ground at Great Bishop Wood and at Forty Acres Plantation is very sandy. Here we have doubtless portions of the passage-beds into the London Clay, and at Brickhouse, on the northern edge of Norsey Wood, sand is seen by the road-side, but from its low level, and in order to maintain as much consistency as possible, it is included with the London Clay. Clay occurs higher up, and where the feature occurs there the sand comes on in force and the boundary-line has been drawn.

The sand was not so well shown at Billericay as at Stock, but it was seen in saw-pits in Norsey Wood, and on the roads south of Birch Wood.

The pebble-beds were worked, for mending the roads, about a quarter of a mile south-west of Brickhouse, where the section was as follows:—

Gravelly loam, a foot.

Bagshot Beds, 8 feet { Pebble-bed (all flints).  
Sand, rather loamy.

PROF. DAWKINS has noted the occurrence of a very few quartz pebbles in a pit in Norsey Wood, perhaps the same as the above.

In 1897 the deep railway-cutting, reaching to the depth of 54½ feet near the Union, gave one of the finest sections of the Bagshot Sand ever laid open in Essex. The beds dip slightly eastward, until reaching the eastern end (not very clear at the time of my visit) when they seem to rise again very slightly, or at all events to flatten. The Bagshot Sand, and its junction with the London Clay, occurred only eastward from the bridge, for the road that is the continuation of High Street. The junction dips from just below the level of this road to about half-way down from the crown of the arches of the higher bridge for the next road eastward; and it was marked by wet, for though a most exceptionally long time of drought had occurred (August 1887) the quantity of water thrown out had given much trouble, entailing drainage-work. Nevertheless, there was no sharp line of division lithologically between the two formations, but really a passage.

The lowest beds were seen only westward from the Station, and the whole succession noted was as follows:—

Wash of pebbles and loam at top in places, on the higher ground. Some large hollows of pebbles E. of the eastern bridge, probably a wash from the pebble-beds of the Bagshot Series, which come on near by, at a higher level.

Bagshot Sand: fine, soft, buff, in many parts with an abundance of black specks and small lumps, and with a few thin layers of clay. Some tiny faults seen. Must reach a thickness of 35 feet or more.

London Clay. { Sandy clay, the lower part very dark, more clayey than some of the beds lower down. P 20 feet or more.  
Sandy beds (clayey sand), shown beneath, just west of the station, where the base is green or greenish.

About a sixth of a mile westward from the Station, on the southern side of cutting, there was brown sandy clay, loam, and clayey sand, grey at the base, the colour-change (due to peroxidation) roughly following the surface; but the connection of these beds with those of the last cutting could not be made out, from parts of the section being hidden, and from the occurrence between this and the Station of what would seem to be a mass of drifted loam, there being a gravel-layer some way down: this however was not clearly seen. Presumably the western beds are the lower. The shallow western end of the cutting is in brown sandy clay and loam.

The short cutting about half a mile eastward of the Station may prove to run through a more southerly spur of Bagshot Sand than has been shown on the map. At top, at the highest part, there is a pebbly wash; then there is fine soft sand, wet at the base, and like Bagshot Sand; then brown sandy clay, grey at the base.

Recurring again to MR. WOODWARD's notes on this district, we learn that patches of very fine sand, just like Bagshot Sand, occur at Outwood Farm, about a mile eastward of Billericay Church, and at Park Hill Wood, about two miles south-west of the church, but from their occurring at a somewhat lower level than the main mass, they have been left with the London Clay. There is however a small sand-outlier by Three Ashes Farm, more than a mile eastward of the Railway Station.

*Stock* (mapped and described by MR. WOODWARD).

The general section here is as below:—

Loam and angular bits of flint, and pebbles	-	2 or 3 feet.
Bagshot Beds { Pebble-beds (all flints)	-	4 to 6 "
{ Brick-earth (laminated in places)	-	3 to 5 "
{ Sand	-	6 to 10 "

At the lowest bed the marked feature occurs. Lower down no good sections are seen; but the soil is very loamy, and seams of sand are observable here and there. There is doubtless a passage into the London Clay.

The pebble-beds were worked at Stock, and they may be seen also at the northern end of the outlier, by the road-side east of Stock Ship, where the beds have been worked out to the brick-earth. "The section shows the pebbles in the form of bands embedded in laminated clay."\*

The sand may be well seen in most of the roads and lanes. In the brick-yard the section is as follows:—

Bagshot Beds {	Patches of pebble-beds.
	Laminated brick-earth, resting obliquely on the bed below.
	Sand.

Stock, otherwise a very healthy place, from its good situation, suffered much, in 1870, from the impurity of the water. This was wholly got from land-springs, issuing from the junction of the sand with the loamy upper beds of the London Clay. From the great amount of sewage that was mixed with the water, the inhabitants, and particularly the children, suffered much from scarlet fever.

There was, I was told, but one well in the village, and probably the water from this comes from the same source.

*Galleywood* (mapped and described by MR. WOODWARD).

At this place, south of Chelmsford, the pebble-beds occur again, but they are accompanied with a good deal of loam. Beneath them is a brick-earth which was largely worked on the southern side of the hill. This I at first took to be Glacial Drift, although MR. S. V. WOOD, jun., regarded it as London Clay. A subsequent examination and survey however of the Bagshot Beds at Stock, Billericay, and Frierning satisfied me of its Eocene age. It clearly belongs to the passage-beds between the Bagshot Sand and the London Clay. The sand was not shown, though MR. WOOD mentions that "slight traces of the base of the Bagshot Sand do occur here."†

\* S. V. WOOD, Jun., *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 464.

† *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 466.

The pebble-beds have been largely dug over Galleywood Common, which is covered with shallow pits (containing water) whence the pebble-beds have been removed. In many instances the pebbles have the longer axis vertical. Mr. BRISTOW has noted that "the gravel is somewhat ferruginous, and interstratified with sand."

South of South Hanningfield there is a small patch of sand. A pit on the spur towards Flemings showed 8 feet of buff sand, with layers of pipe-clay, and the lane south of the inn showed 7 feet of sand.

At Danbury the Glacial gravel occurs at a very high level (366 feet). It is probable that here a patch of the Bagshot pebble-beds was left after the main denudation of the country, for Mr. PENNING noticed the very pebbly nature of the gravel in some places on the hill, a feature doubtless due to its being largely made up of these old pebble-beds.

H. B. WOODWARD.

### *South of the Crouch.*

The outliers of this district were mapped by Mr. BRISTOW, whose notes will be used in their description, with some later ones of my own.

### *Langdon Hill.*

This well-marked hill, which stands out from the surrounding lower country and can be seen from long distances, consists of an outlier of sand, much capped by pebbles. About a quarter of a mile south of West Lee Hall, on the northern side of the road, a sand-pit gave the following section, in 1888 :—

Brown clayey beds, finely bedded, a few feet.

Light-coloured sand, with some miniature faults; about 12 feet seen, and pierced to a further depth of about 16 feet in a well close by (see *post*).

This seems to be the pit noted originally by Mr. BRISTOW, who says of the sand that "it is for the most part grey and dry, but water is thrown out at the junction with the London Clay, in the road on the north." Probably, however, from what Mr. GILBERT, of Langdon Hill, tells me, the water comes out above that junction, and the boundary-line may be a trifle lower than it has been engraved.

Layers of pebbles were seen in the sand at the northern end, in a small pit on the eastern side of the road near the "Trigonometrical Station" (1872), and Mr. WOODWARD notes that "the pebble-beds seem to have been worked at a lower level westward of Coombe Wood, as flint-pebbles only are found in the numerous holes."

On the older edition of the map (Sheet 1, S.E.), on which Drifts are not shown, this hill is marked as covered by the pebble-beds: on the Drift edition however the same tract is coloured as Pebble Gravel. Probably a difficulty was found in dividing the two; but a visit made in 1888 led me to think that the latter, at all events, does not cover so large an area as the former; for the characteristic of the soil over the southern half of the small tract in question is the abundance of flint-pebbles, to the exclusion of other stones, and, in a small pit on the Common, a little N.E. of Goldsmith's Farm, there was a distinct trace of the pebble-bed over sand.

At Lime Wood and Old Hill, close to the above, are small patches. A more marked mass occurs about half a mile south of Dry Street, and the beds are clayey enough to supply a brickyard, the pit at which (in 1872) was from 25 to 30 feet deep, in sand with layers of pipe-clay, showing a considerable south-easterly dip and some small faults. At the top a mass of clay scooped into the sand, and in a shallow section this might be mistaken for London Clay.

Above Vange are three more outliers, one half a mile west of the church, one at Vange Hall, and the other just eastward.

### *Rayleigh and Hadleigh.*

A large irregular mass has been mapped over the higher ground from South Benfleet and Hadleigh northward to Hockley.

It seems likely that, in the northern part of this tract at all events, MR. BRISTOW may have taken a lower base for the Bagshot Beds than MR. WOODWARD has done, to the west, or else the sand is to some extent replaced by clay, for along the high road north-eastward of Rayleigh, where the level falls slightly (to little over 200 feet above Ordnance Datum) the ground is decidedly clayey, and the tract to the east looks as if it were formed of clay rather than of sand.

Sand was seen in the garden of a new house on the western side of the road about an eighth of a mile N.E. of Rayleigh Church, and under the eastern hedge of the road there is sand and gravel cemented by iron-oxide (1887).

The following quotations are from MR. H. W. BRISTOW'S Notes.

"The Rectory House (Rayleigh) and the garden belonging to it, on the western side of the road, are upon a level piece of land formed of a capping of pebble-gravel overlying sand." (MR. S. V. WOOD, jun., has noticed the pebble-bed of the Bagshot Series here.)\*

"At the brickyard (abandoned now) south of the town the bricks were made of an ash-grey and pale ferruginous sandy clay, which was seen to a depth of 5½ feet. There is no gravel here, but merely a covering of sandy soil on an uneven surface of the brick-clay, for a depth of a foot to two feet, and containing occasionally small flint-pebbles and a few small angular fragments of flint irregularly scattered at rare intervals. The clay is laminated and much undulated, and the general direction of the dip is northward. The three feet next beneath the stony part were used for tiles and pipes, and the next 9½ feet yield a good brick-clay. Under this is about 12 feet of much stiffer clay, pale chocolate-brown, and ash-grey, hard, tough, and with nodules of iron-pyrites (of various shapes and sizes), and pieces of iron-sand, which latter harden and become black in burning and make the tiles hard. When used for making tiles the clay was mixed with sand brought from Thundersley; for making pipes no sand was used. At the bottom of all is a black running sand full of water, not sunk through at a depth of about 3 feet."

"Pale yellowish sand is shown on the southern side of Round Hill, westward of Hadleigh, where it forms a steep escarpment, and in like manner between Hole and Castle Farms. In both cases the ground at the lower part of the escarpment is overgrown with fern, and at a lower level with rushes, and becomes broken and uneven in consequence of the slipping of the higher beds over the wet and springy junction with the London Clay, thus hiding the true boundary between the two formations, and causing the Bagshot Sand to have an apparent extension over a larger area than it really takes up."

"Like escarpments occur on the eastern side of the hill, but to a less degree."

E.S.E. of Rayleigh two small outliers have been mapped: one stretching from Edwards Hall westward for about a mile; the other at Newhouse. (The most westerly of the two places so-named on the old one-inch map, and called Wyburns on the six-inch map.)

At Hockley Church and Plumberrow Mount (to the E.N.E.) other very small patches have been mapped.

The patch mapped along the high ground southward of Hockley Spa, consists, in my opinion, only of the sandy top beds of the London Clay (see p. 261).

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It may be noted that the outliers of High Beach, Havering, Brentwood, Langdon Hill, and Rayleigh were recognised as Bagshot Sand by PROF. PRESTWICH in 1854.†

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\* *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 466.

† *Ibid.*, vol. x. pp. 402-407.

## CHAPTER 18. DEPOSITS OF DOUBTFUL AGE.

Before taking up the description of the various Drift beds, of the age of which one can be fairly certain, or which can be classified stratigraphically, it will be convenient to leave our ordinary stratigraphic arrangement and to deal with a miscellaneous set of deposits, either of uncertain age or origin, or which, in some cases, may have been formed during a long period, and may therefore be of different ages in different places. It should be understood that the grouping together of these deposits by no means implies that they have any relation to each other; but is only adopted here as a mere matter of convenience, or, if the reader likes, as a confession of ignorance and of inability (in part at least) to refer the deposits to their proper place in the geologic sequence.

It must sometimes happen, in detailed geologic work, that one can say little more of a certain deposit than that it occurs in certain places and positions, and that it has a certain composition. From the fact of such a deposit not occurring beneath any other, but only as a capping, one is sometimes not enabled to assign an upward limit to its age, but must be content, as my old friend and teacher PROF. JOHN MORRIS put it, to say that a gravel is "somewhere between the Bagshot Sand and the Moon." So far one may safely go with the beds now to be described, and sometimes further.

This Chapter must therefore be taken as a sort of interlude between the acts of the play, to wile away the time whilst the scenes are being shifted from the Eocene to the Post Pliocene age.

### CLAY-WITH-FLINTS.

#### *General Account.*

This name was given by the writer, in 1861,\* to a deposit of stiff brown and reddish clay with large unworn flints, that occurs over the higher parts of the Upper Chalk tract, on the plateau that is to say. It was given without knowing that a like deposit in France had been given a like name, *argile à silex*, and that it had a literature in that country.

This clay lies very irregularly on the Chalk, filling pipes in that rock, and never occurring as an even overlying bed (like the Thanet Sand or the Reading Beds). At the base there is generally black clay, a few inches thick, also with flints, in this case black-coated. It does not occur in the bottoms of the valleys, though often running some way down the upper part of

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\* Memoirs of the Geological Survey. The Geology of Parts of Oxfordshire and Berkshire (Sheet 13), pp. 54, 55.



their slopes, and it is practically confined to the tract taken up by the Upper or flinty Chalk.

Besides the unworn flints, there are also sometimes pebbles of flint and of quartz, as well as, more rarely, pieces of old rocks, in the Clay-with-flints. These may have been derived from Tertiary or Drift beds that have been worn away.

As to the range of this bed, enough to say that it occurs over nearly the whole of the higher parts of the chalk-district, giving rise to a stiff heavy soil, altogether doing away with chalk-downs, and supporting great quantities of timber. Its thickness is ever varying, owing to its irregular lie on the Chalk; so that whilst at one spot there may be but a foot of it, at another, only a few yards off, it may reach to a depth of 20 feet or more.

At first I could not satisfy myself as to the origin of the deposit, but had to be content with a mere descriptive notice. Further knowledge, however,\* led me to think that the Clay-with-flints is of many ages, and may be forming even at the present day, and that it is owing in great part to the slow decomposition of the Chalk under atmospheric action. If a chalk-district were exposed for thousands of years, as many such districts must have been, to the action of rain, &c., the result would be that the carbonate of lime would be slowly carried away in solution, by the carbonated water flowing through the cracks and joints of the absorbent rock, and leaving behind the insoluble compact flints and great part of the earthy matter and iron. To these would be added the clayey and loamy wash from the Tertiary-lands, and the remains of beds of that age left in pipes and hollows in the Chalk. The irregular-shaped flints would help in catching and holding the earthy matters, the iron would give a brownish-red colour to the whole, and the irregular decomposition of the Chalk would cause the resultant deposit of these actions to have a varying thickness and an irregular position. The clay and flints left by the dissolution of the Chalk would be present almost everywhere; whilst the loamy materials that would be formed from the lowest Tertiary beds would most likely be more local. The fact of the Clay-with-flints occurring only on the Chalk-with-flints is in favour of this view; and it is perhaps owing to the comparatively small amount of more or less flat surface taken up by the Chalk-without-flints that there is no such deposit on it. This lower and middle divisions of the Chalk form by far the greater part of the slope of the high escarpment and the latter crops out also for some distance on the flanks of the valleys, but the Upper Chalk alone occurs over the wide-spreading table-land.

The unworn character of the flints, some of which seem to have their original surface almost as fresh as if they had come direct from the Chalk (save for their dark staining), shows that the

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\* Memoirs of the Geological Survey. The Geology of Parts of Middlesex. (Sheet 7). 1864. Here reproduced.

deposit has been formed on the spot where it is found and not from transported material.

Of course such a process for the origin of the Clay-with-flints as that above described requires a great length of time, and may have gone on at some depth from the surface, where water could get at the Chalk. It may too be still going on, so that a thin lower deposit may be formed beneath an older though higher one.

The bottom-bed of the Reading Beds sometimes looks not unlike this deposit, owing, I suppose, to the decomposition and peroxidation of the protosilicate of iron which gives the green colour to the flints in that bed; and I take it that the Clay-with-flints may be in part older than any of the Post-Pliocene beds; its formation having begun at whatever time the Chalk was within reach of atmospheric agencies, and gone on up to the present time; so that it is also amongst the newest deposits.

Northward of our district, in parts where the Chalk is much covered by Boulder Clay, traces of Clay-with-flints are rarely found. MR. H. B. WOODWARD suggests that this "may be owing to the incorporation of any pre-existing accumulation of the sort, together with much of the Chalk itself, in the Glacial Drift." The presence of a thick mass of impermeable Boulder Clay would tend to hinder any such accumulation in Post-Glacial times, and what little occurs in such tracts is usually as a fringe to the Boulder Clay.

The facts that in nearly all limestone-districts there is a red soil, and that there is always a red earth in limestone-caves, add I think to the likelihood of the above being the right view of the case. It was not, however, new, as will be seen by the following quotation from a paper by the late MR. J. TRIMMER, who paid great attention to surface-beds, and who disagreed with this view:—"I propose to show that the soils which cover the chalk of Kent (much the same as in our district) . . . are the result of aqueous transport; and not, according to the prevalent assumption, produced by atmospheric erosion which during the lapse of ages dissolved and removed the calcareous matter of the chalk, leaving behind, as upon a filter, its fine siliceous and argillaceous particles and its flints."\* I neither know who were the holders of the "prevalent assumption," nor can I find any earlier statement of it than the above; but it may be remarked that Mr. Trimmer was not disposed to allow that the chemical action of carbonated water had any sensible effect on the Chalk, as far as can be judged from his published papers, and that he here groups together the Clay-with-flints, the Brick-earth, and other materials that may perhaps be merely the result of rain-wash down the hill-sides. The unworn and often unbroken character of the flints in the clay is surely in favour of the notion that the deposit is not owing to transport, which would have rounded off the corners and edges of the flints.

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\* *Quart. Journ. Geol. Soc.*, vol. vii. p. 84 (1851).

It is difficult to account for the blackness of the clay next to the Chalk. Can it be caused by the infiltration of water with decomposed vegetable matter in solution, or to the action of iron on such matter (forming a sort of natural ink)?

At about the same time as my theory of the origin of the Clay-with-flints appeared, my friend MR. T. CODRINGTON came to a like conclusion, but making the presence of an overlying clayey material, such as brickearth, an essential condition. In treating of a tract many miles westward of that with which we are concerned,\* he wrote as follows:—"Everything seems to indicate a quiet subsidence of the overlying bed into irregularities in the dissolving chalk. Everything here also favours the supposition, that the origin of the Clay-with-flints is to be ascribed to the gradual dissolving away of the Chalk-with-flints under a capping of drift Brick-earth. The flints . . . have subsided gradually, without losing any of the irregularity of their forms. The overlying drift or Brick-earth has also sunk, the clay and sand and a few small tertiary pebbles [of flint] finding their way around and below the flints as the chalk enclosing them was dissolved . . . The Clay-with-flints *must* underlie the Brick-earth, when the latter is present, but the whole of it may be absorbed into the Clay-with-flints. Upper-chalk-with-flints must be the under-lying formation to furnish the flints. . . . A covering of drift, made up of Tertiary materials, seems greatly to promote the formation of potholes, and the irregular erosion of the chalk."

I am glad to be able to quote the opinion of one of the greatest observers that the world has seen in favour of the theory of the origin of the Clay-with-flints that is here brought forward, and I would draw attention to the explanation given by DARWIN of the more or less vertical position of many of the flints, an explanation that calls in the aid of no force beyond what must naturally be present, and that shows the needlessness of imagining glacial or any other exceptional action.

"During the dissolution of the chalk, the insoluble matter, including a vast number of unrolled flints of all sizes, has been left on the surface and forms a bed of stiff red clay, full of flints," and, in a footnote, he goes into detail as follows:—"These pits or pipes are still in process of formation. During the last forty years I have seen or heard of five cases, in which a circular space, several feet in diameter, suddenly fell in, leaving on the field an open hole with perpendicular sides, some feet in depth. This occurred in one of my own fields. . . . The subsidence occurred where there was a broad depression, as if the surface had fallen in at several former periods. . . . The rain-water over this whole district [Down, West Kent] sinks perpendicularly into the ground, but the chalk is more porous in certain places than in others. Thus the drainage from the overlying clay is directed to certain points, where a greater amount of calcareous

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\* The Geology of the Berks & Hants Extension, and Marlborough Railways. *Mag. Wilts. Archaeol. Nat. Hist. Soc.* 1865.

matter is dissolved than elsewhere. Even narrow open channels are sometimes formed in the solid chalk. As the chalk is slowly dissolved over the whole country, but more in some parts than in others, the undissolved residue—that is the overlying mass of red clay with flints,—likewise sinks slowly down, and tends to fill up the pipes or cavities. But the upper part of the red clay holds together, aided probably by the roots of plants, for a longer time than the lower parts, and thus forms a roof, which sooner or later falls in . . . The downward movement of the clay may be compared with that of a glacier, but is incomparably slower; and this movement accounts for a singular fact, namely, that the much elongated flints which are embedded in the chalk in a nearly horizontal position, are commonly found standing nearly or quite upright in the red clay. . . . These elongated flints must get placed in their upright position, on the same principle that a trunk of a tree left on a glacier assumes a position parallel to the line of motion. The flints in the clay which form almost half its bulk, are very often broken, though not rolled or abraded; and this may be accounted for by their mutual pressure, whilst the whole mass is subsiding.”\*

Only lately have I known more certainly that my theory of the formation of Clay-with-flints was far from being new; that it had occurred to SIR C. LYELL and to PROF. PRESTWICH, judging at least from the following extract:—“There was a meeting lately at the Geological Society, at which Prestwich (judging from what R. Jones told me) brought forward your exact theory, viz. that the whole red clay and flints over the chalk plateau hereabouts [Down, Kent] is the residuum from the slow dissolution of the chalk!”† Unfortunately however there is no printed record to this effect, in the case of either author, and the view seems not to have been published. The paper referred to is probably that “On the Origin of the Sand- and Gravel-Pipes in the Chalk;”‡ but it contains no account of the origin of the Clay-with-flints. Perhaps the theory in question came out in discussion. MR. PRESTWICH writes that, as well as he can remember, he referred only to the unworn flints in the clay.

It would take much time to give an account of the views of French geologists on deposits of this kind, and one is forced therefore to pass them by, merely remarking that many theories have been advanced, and that there is at last a tendency to come to an explanation of the kind above given, which seems to have escaped the notice of our friends over the water. One must refer however to the admirable account of this and many other surface-alterations by M. E. VAN DEN BROECK,§ who has worked out such subjects in detail in Belgium.

\* DARWIN. “The Formation of Vegetable Mould, through the Action of Worms,” pp. 187–189. 8vo. London. 1881. The subject again referred to, p. 298.

† Letter from C. DARWIN to C. LYELL, 18 Feb. 1854, in “The Life and Letters of Charles Darwin.” vol. 1., p. 391. (1887.)

‡ *Quart. Journ. Geol. Soc.*, vol. xi. p. 64. (1855.)

§ “Sur les Phénomènes d’Alteration des Dépôts superficiels par l’Infiltration des Eaux météoriques.” *Mem. cour. Ac. R. Belg.* t. xlii. 1881.

*Details.*

Sections are to be seen along road-sides, in shafts sunk for Chalk, and in bickyards, which last will be described under the next heading.

South of the Thames, in Berkshire, only four patches have been mapped, between Henley and Bisham. In one of these the northern side of the cutting on the high road south of Remenhall, up the hill on the eastern side of the Thames opposite Henley, gave the best section that I know of in the district.\* The Chalk-with-flints is flat-bedded in the direction of the road (E. and W.) and the surface-clay comes on suddenly on the east in a great pipe, which reaches down to the level of the road, a depth of about 30 feet. Higher up, further east, the Chalk reaches nearly to the surface again, and then there are more pipes, all connected at the top, so that the clay is continuous along the rest of the cutting. Next to, and for a little distance from the Chalk there is dark brown and black clay with unworn black-coated flints; the other contents of the pipes are brown and red clay, brown loam, brown, red, yellow, and buff sand, and brown gravel, all irregular and with flints, unworn, worn, rounded and a few green-coated (from the bottom-bed of the Reading Beds). There are also pebbles of quartz, quartz-rock, and other old rocks, and a few small lumps of ironstone. Here and there are black streaks or veins in the beds, and sometimes a patch of blackened gravel. The flints exceed all the other stones both in size and in number, many being very large.

MR. H. B. WOODWARD notes that at Upper Culham "Clay-with-flints occurs to a depth of about 15 feet, and covers a fair area. There is also in this neighbourhood a thin loamy soil, with a few pebbles and bits of flint over the Chalk, enough to give a clayey appearance to the fields. This loamy soil is washed down into the valleys, and then obscures the boundary of the River Gravel. There is a like soil over Prospect Hill (south of Hurley), Pinkney's Green, and The Mount (Cookham Dean)," very likely the result of wash from the hills of the Tertiary beds.

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On the flank of the chalk-escarpment, about a mile S.W. of Bledlow, I saw a pipe of Clay-with-flints, 15 feet or more deep, going from the Chalk-with-flints through the Chalk Rock into the Middle Chalk.

In a field at the southern edge of Pophleys Wood, northward of Storkenham Common, I found at one place a number of very small black flint-pebbles, from the size of small shot to that of slugs, in the clay.

MR. J. H. BLAKE notes that "from Storkenham Common southward, at the western edge of the district, a thick mass of Clay-with-flints occurs over a considerable area, being as much as 30 feet or more in depth in parts. On one side of a shaft, sunk through to Chalk, the clay was 8 feet deep, whereas on the other it was 28, showing the great uncertainty as to thickness. Much Clay-with-flints also occurs southward of the Lane End Tertiary outlier."

Of the district north of High Wycombe MR. F. J. BENNETT notes that "the Clay-with-flints occurs mostly on the spurs of the hills, the highest ground consisting of brickearth."

MR. H. B. WOODWARD remarks that "the irregular character of the Clay-with-flints is very noticeable about High Wycombe. The fields often have a loamy or clayey soil, while a chalk-pit in the same land shows but a trace of soil. Sometimes when boundaries of Clay-with-flints and brick-earth have been traced round a high tract of chalk, on walking over the intermediate ground, where one would naturally expect to find these deposits reach their greatest thickness, a pit, with chalk bare to the surface, unexpectedly turns up. It is necessary to disregard pits of this kind, and merely to note their position, otherwise whole tracts of ground, if one judged at all by levels, must be mapped as bare chalk, when that is in fact the exception and not the rule."

"At Oakridge, west of Wycombe Abbey, there is a thickness of between 4 and 5 feet of stiff reddish clay-with-flints, in places sandy and pebbly."

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\* This cutting has been noted by DR. BUCKLAND, *Rep. Brit. Assoc. for 1839, Sections*, p. 76, and by PROF. PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xi. p. 71.

"Clay-with-flints occurs on most of the hill-tops, near Chesham, and may be seen in the lanes leading up to them. On the highest ground it is generally covered by brick-earth. It frequently occurs down gentle slopes, almost to the bottom of the valleys, and again, in three or four instances, bare Chalk occurs on the very highest ground of a ridge. Brick-earth appears to occur on the Chalk without the intervention of any Clay-with-flints, or with merely a trace of it, at the end of a ridge; the apparent absence of the clay may be due to its extreme thinness, and this, combined with the frequent sharpness of the slope of the hills, sometimes prevents any appreciable trace of it from being mapped."

"Some of the fields near Chesham are literally covered with flints, mostly broken, and it is a wonder how anything can grow, there is so little soil; turnips and mangel-wurzel however seem to thrive."

MR. W. A. E. USSHER notes that "on the southern side of Layhill Common, about two miles east of Chesham, there was (in 1869) a section of very irregular, reddish-brown, greenish and blackish Clay-with-flints, with included masses of buff brick-earth and loamy gravel, mostly of pebbles but partly of angular flints, the whole apparently filling a pipe in the Chalk."

MR. A. G. CAMERON sends the following note, made in 1887:—"In a new road-cutting westward of Hemel Hempstead, up the side-valley that joins the Bulbourne Valley at Crouch Field, and running from the road skirting the western side of Lockers Park downward, in a southerly direction, for a length of about a sixth of a mile, and to a depth of up to 8 feet, a mass of Clay-with-flints rests very irregularly on soft chalk with many flints (some large), and at one end passes under a sandy gravel, with many flint pebbles."

MR. R. TRENCH, in first making the Geological Survey of this part, noted that "at Wood Lane End, east of Hemel Hempstead, the Clay-with-flints contains large black brittle paramoudra-shaped flints."

MR. H. B. WOODWARD has supplied the following notes:—

"Round St. Albans this irregular deposit varies from a few inches to 4 or 5 feet in thickness. Pebbles and loam are frequently mixed up with it."

"Clay-with-flints is well exposed in a pit at Gorhambury Park, by the fence S.W. of the Ruin. The section shows stiff reddish-brown clay with a few large paramoudra-shaped flints, and some small unworn flints, to about 4 feet."

"Clay-with-flints may be seen at St. Julians, Bone Hill and Plasters, southward and south-westward of St. Albans."

"Good sections may be seen by the Toll-gate and by the Great Northern Railway Station, St. Albans."

"On the Midland Railway, by Dell Farm, chalk is exposed with pipes of clay-with-flints, gravel, sand, and loam; the same sort of thing occurs in the cuttings by Hounds Wood, near Radlett, where pipes of clayey greensand (Reading Beds) also occur, mixed up with the other materials."

"At Hedges Farm stiff brown clay with a few unworn flints, 4 or 5 feet in thickness, was seen in saw-pits."

"A trace occurs on the Great Northern Railway by Hoxley's Pond, Hatfield Park, loam with many pebbles being mixed up with the clay."

## BRICEARTH ASSOCIATED WITH THE CLAY-WITH-FLINTS.

### *General Description.*

A more valuable deposit than the Clay-with-flints, consisting of loam, and formed perhaps by the mixing up of the sands and clays of the Reading Beds, is not uncommon over the chalk-tract, and is often worked for brick-making. It is of various colours and composition, sometimes being dark-brown, bluish-grey and red-mottled, and sometimes light-brown; whilst at one place it is a sandy clay, at another a clayey sand. Like the Clay-with-

flints, by which it is underlain, it occurs irregularly, filling pipes, often of large size.

Where of a bright red-mottled tint it has sometimes been taken to belong to the Reading Beds; but it can be distinguished on careful examination, both colour and material being less pure than those of the richly hued mottled clays. Sometimes masses of these, and of the sand of the Reading Beds, are included in the brickearth, which one is then the more disposed to regard as resulting from the mixture of the clay and sand.

MR. H. B. WOODWARD says that "much of the brickearth near Chesham, and especially that to the west, contains many large unworn flints. So abundant are these sometimes that the deposit may be mistaken in many instances for Clay-with-flints, and the boundary between the two is very doubtful." To me indeed it has always seemed difficult to divide the two, and that the attempt to do so was not satisfactory. It be may a question whether it would not be advisable to drop the division, mapping the two deposits together, as Brickearth bordered by Clay-with-flints.

There is another doubtful point in regard to this high level loam, namely, whether all the various masses are of the same geologic age. It is very likely indeed that whilst some are mere relics from the denudation of the Tertiary beds, let down into pipes in the Chalk, others, and especially those where a bedded structure is apparent, may belong to the Glacial Drift.

#### *Details.*

At Highfield Barn, nearly a mile west of Hambledon, there has been a brickyard; the pit, about 15 feet deep, showed (in 1858) a gravelly soil, from a foot to four feet thick, over the brickearth (light-brown clay, loam, and sand). At one part there was gravel below, and this most likely occurs under all parts; it was sandy at one place, clayey at another, and consisted of flint-pebbles, flints, and pebbles of quartz and of sandstone. Some of the brick-earth was pale blue mottled with red.

MR. J. H. BLAKE notes that "near East Wood (Storkenham Common) loam, sand, mottled clay, and clay-with-flints seem to be much intermixed. North of Chequer Farm (by Chequer Common) loam with sand and gravel occurs. Around Park Hill and in the neighbourhood of Wheelers End Common, north of the Lane End Tertiary outlier, loam occurs."

MR. H. B. WOODWARD adds that "at Barmor, eastward of the Tertiary outlier, though the soil is very loamy, there is probably but little thickness of loam, and at New Moor, northward of Booker Common, sand, mostly brownish, though light-coloured at the bottom, has been dug to a depth of 7 feet; but this is probably a pipe of the Reading Beds."

At Marlow Common, west of Great Marlow, the brickearth is irregularly capped by a sort of clayey gravel, and underlain, I was told, by clay with large flints, beneath which again was rubbly chalk.

In an old brickyard at Flackwell Heath, about three miles S.E. of High Wycombe, I saw some 12 feet of brick-earth and gravel above chalk.

N.W., N., and N.E. of Wycombe this deposit occurs in abundance on the high ground, and is in parts remarkable for containing very many blocks of greywether-sandstone, for which indeed the brick-earth is then worked rather than for brick-making. Small pits are dug in the fields, the stones are quarried out and then broken up into small cuboidal blocks, for paving and building. The pounding action of the hammer reduces part of the hard stone to a coarse light-coloured sand, like that of the Reading Beds.

At Nobles, just westward of Bradenham, the greywethers have been thus got; and at Napple Common and around Walter's Ash, to the east of that village, the brick-earth, sometimes proved to a depth of 30 feet, and then not bottomed, contains many and large greywethers at different depths, and often so close together as almost to form a continuous bed, so much so that PROF. PRÆSTWICH was led to think them nearly in place.\*

At Speen Hill, S.S.W. of Hampden, there was a brickyard, and southward of this village greywethers were again quarried from the brick-earth at Denner Hill, and on the western flank of Bryant's Bottom, at which last place the greywether-bearing deposit spreads from the top of the hill down into the valley. It also runs northward to Hampden Row, and again occurs about half way between Hampden and Prince's Risborough.

At the northern end of Clinton Wood, nearly two miles S.W. of Wendover, the brick-earth was worked.

A great spread of it stretches from Priestwood, E.S.E. of Hampden, to Common Wood and to Winchmoor Hill, N. and N.E. of Penn.

At the northern end of Priestwood Common there was a brickyard, where I saw (in 1866) a pit about 12 feet deep in the brickearth, the upper part of which was mottled, and with flints; whilst the lower was brown, and free from stones. Just above was a section showing some thickness of flints in loam.

Over Wycombe Heath and Penn Wood (now enclosed) and thence toward Winchmoor Hill, there is brick-earth, which was worked just south of Penn Street; and again between these parts and Wycombe. At the brickyard (Terrier's Kiln), between Hazlemoor and Terrier's, some of the pits, on the southern side of the road, showed the loam (in parts very red, at others light-coloured, and at some containing a little mottled clay from the Reading Beds). It has been dug to a depth of 30 feet without reaching the Chalk, whilst close by to the west there is a chalk-pit, and at the kiln, on the other side of the road, chalk is also got, there being only clay-with-flints, in parts with some mottled clay, above it. At a later date Mr. H. B. WOODWARD has recorded "15 feet of clean brickearth, bright and mottled, capped by an irregular gravelly soil," and he adds that "towards Common Wood the loam is of considerable thickness."

Between this last place and Penn were two more brickyards, and near the houses on the common, just north of Ash Hill, were pits which showed the following beds, very irregular, but in this order:—

Red-mottled brick-earth, gravelly in parts (chiefly at top).

Gravel, almost wholly of flint-pebbles.

Brown and black clay with large unworn flints.

Chalk found below.

MR. C. E. HAWKINS notes that "a pit just inside Great Wood, near Whites, some two miles eastward of Penn, showed 4 or 5 feet of brick-earth, capped by a little pebbly soil."

There is a brickyard in this deposit on the northern side of the high road a mile west of Beaconsfield, and another section is given by the deep road-cutting further west (see p. 301).

E. and S.E. of Wendover is a wide-spread mass of brick-earth. At Buckland Common there are two old brickyards, and a third, in work, showed that the "earth" is very sandy and brightly coloured, being sometimes a pink clayey sand, much like parts of the Reading Beds.

MR. WOODWARD says that at the brickyard north of Lee, "there was a very good section, the loam being of a very irregular character, partly full of flints, but partly (even in the same pit) almost free from them."

MR. C. E. HAWKINS has noted "about 4 or 5 feet of very sandy brown loam, without flints or pebbles, in a small pit near Berry Farm, a mile N.E. of Great Missenden," and "good brick-earth on the road running north-westward from Barley Mow to the south."

At Hyde Heath brickyard, east of Great Missenden, blocks of pudding-stone have been found in the brick-earth, of which there seems to be two sorts, the lower part being of a lighter colour than the upper. At a later date Mr. HAWKINS saw "about 15 feet of brick-earth, in some of the pits free from flints, in others the reverse."

\* *Quart. Journ. Geol. Soc.*, vol. x. p. 127.



The brick-earth at Wigginton Common is also worked, but the brickyard is just beyond the boundary of our district.

Between Amersham and Chesham there is a little brick-earth.

MR. W. A. E. USSHER contributes the following notes : —“Near the wood south-east of Thorn (N.N.E. of Chesham) were two pits showing pinkish and brownish loam on stiff brown and reddish clay with a few flints.”

“Nearly a quarter of a mile west of Ashlyns Hall (or S.W. of Berkhamstead) I saw a pipe of stiff blue clay in the red and bluish-grey mottled laminated brick-earth.”

“In Box Lane, southward of Little Hay (or S.W. of Boxmoor) there is candy laminated brick-earth, light-red and yellowish.”

At Shendish, N.N.W. of King's Langley, brick-earth has been worked.

At Wood Lane End brickyard, more than a mile east of Hemel Hempstead, there was a very good section, which I saw in company with Dr. Evans, of Nash Mills, showing 25 feet of brick-earth, containing a few pebbles and flints, and more or less laminated, especially the lower part. The upper part is brown and yellow; the lower buff and whitish, and consists of finely and evenly laminated clayey sand, in which DR. EVANS found an impression of a small *exogenous leaf*. The beds dip inward toward a centre, sometimes at as great an angle as 35° or 40°, and therefore fill a basin or trough-shaped hollow. MR. USSHER notes that “in other parts of the yard there was the usual mottled pink and grey brick-earth.” The clay-with-flints is also well shown here.

A large mass extends over the hill-tops from Leverstock Green, S.E. of Hemel Hempstead, southward to the east of Abbot's Langley, and eastward toward St. Albans.

At Bennet's End, a thickness of 30 or 40 feet of brick-earth is shown at the more northerly brickyard. The earth is mottled bluish-grey, scarlet, and brown, in some parts very light-coloured, in others very bright, and it contains pebbles and flints. MR. TRENCH noted that “from 50 to 70 feet of brick-earth have been found here above the Chalk.”

About a mile and a half S.E., in the road-cutting just south of where Hagdale Lane turns off, there are blocks of pudding-stone and paramoudra-flints in pebbly brick-earth.

MR. USSHER notes that “westward of Sheppeys, north of Abbot's Langley, there are pebbles and blocks of pudding-stone in the brick-earth.”

In the Brickyard near Sheppeys, at the southern and lower end there was, in 1869, a long shallow cut in brown bedded loam, like the basement-bed of the London Clay, (with an irregular cap of pebbles) and mottled plastic clay. These may be a piped mass of Eocene beds. At the northern part is a chalk-pit with an irregular cap of brown loam and clay, with flint-pebbles and green-coated flints at the bottom. MR. USSHER notes that “there is also pinkish-red and grey mottled sandy brick-earth.”

MR. WOODWARD describes the eastern limbs of this mass as follows :—“Beech Tree, Pre Wood, Birch Wood, Park Wood, etc., are on a gravelly loam, of trifling thickness and of no economic value [for brickmaking]. According to a farmer, Windridge is on stiff bright-red brick-earth, holding water, and with gravel underneath. At Potters Crouch there is red sandy brick-earth; and south of Park Wood a little sand. A well at the inn at Chiswell Green passed through 6 or 7 feet of loam to chalk, according to the landlord.

“From Serge Hill by the Holt to Lye Lane there is again gravelly or pebbly loam, and also by Fortunes and High Elms, eastward of Abbot's Langley. In these parts the boundary between the brick-earth and the gravel is not generally well defined.”

Probably in these masses we have passed to brick-earth belonging to the Glacial Drift, as it seems to be underlain by the gravel of that formation.

## PEBBLE GRAVEL.

### *General Description.*

We now come to a deposit which can be safely inferred to be the oldest Drift-bed of our district; but even in this case some

patches, probably of later date, have been shown on the maps by the same colour as this old gravel, as a matter of convenience, their composition being much the same, and it being almost impossible to give a separate colour to every different indeterminate bed. It should be understood therefore that sometimes the colour on the map refers rather to the pebbly composition of the gravel than to its age. In the detailed description the doubtful masses will be duly noted.

The following general account is taken, with some slight changes, from the "Guide to the Geology of London," in the four editions of which this gravel was noticed (1875-1884).

On the tops of the Tertiary hills there is often a capping of sandy gravel of a somewhat exceptional sort, that is to say, it is almost wholly wanting in the more or less angular pieces of flint that form the greater part of the other gravels to be described, and, like the far older gravel-beds of the Blackheath and Bagshot Series, which have been already described, its component stones have been rounded into the form of pebbles.

Showing at first sight a very great likeness to the old Tertiary pebble-beds, after a more careful examination this gravel is seen to be easily distinguished from them; for whilst the pebbles of the former are of flint only, that is not the case with the latter, which contains also a large proportion of pebbles of quartz and of quartzite, and here and there a sub-angular flint. Were this gravel roughly sorted, it would mostly be found that amongst the larger pebbles those of flint were in excess, whilst amongst the smaller those of quartz were most common; sometimes indeed the small rounded pieces of white quartz give the gravel a very distinctive appearance.

The flint-pebbles have been derived from the destruction of old Tertiary pebble-beds; but the pebbles of quartz, of quartzite, and of other older rocks that occasionally occur, must have been almost wholly derived from beds that do not crop out anywhere in our district.

Of the age of this gravel we cannot speak with absolute certainty: we can only infer. It is newer than the Bagshot Sand, for it is known to overlie this; and it is older than the Boulder Clay, which is found above it, but between these extremes we are left to reason by analogy and by the evidence given by the manner of occurrence.

In the first place it is not likely to belong to any part of the Bagshot Beds, as it is unlike any part of them (differing from the pebble-beds of that Series in containing quartz-pebbles in great abundance), and as it rests both on their lower member and also on London Clay. Secondly, it is unlike the Crag beds of Suffolk, which, moreover, are not known to occur anywhere near our district. It would seem, therefore, to belong to the Drift, and the question is practically limited to the relation of this gravel to the other Drift beds.

Nowhere do we see its relation to the sands, gravels, &c., which so commonly occur beneath the Boulder Clay, and which

have been named Middle Glacial by MR. S. V. WOOD, JUNR., and consequently it is open to class it with those beds, as that observer did. MR. WOODWARD remarks that "in the neighbourhood of Barnet and Finchley it was found difficult to distinguish between Pebble Gravel and Glacial Gravel, and, the mapping having been done by different persons, perfect consistency was hardly possible."

But, on the other hand, it may be urged that the Pebble Gravel is distinct from that of undoubted Glacial age, and to my mind the balance of evidence is in favour of this conclusion, for the former is different in composition from the latter (in the comparative want of sub-angular flints), and it has never been found to contain the layer of Boulder Clay that so often occurs, though not in our district perhaps, in the Glacial gravel.

From its occurrence on the tops of the hills, whilst the Glacial gravel often lies at their bases or on their flanks, it would seem that the Pebble Gravel is the older of the two, and that it was deposited before those hills were cut into their present form, a process which must have been somewhat advanced before the Glacial gravel was laid down. It is possible, therefore, that the pebble-gravel may represent some part of the Lower Glacial of MR. WOOD, any known occurrence of which, however, is about as far distant as Crag.

Whilst carrying on the Geological Survey in parts of Eastern Suffolk it occurred to me that the Pebble Gravel of the district now under notice might represent a like deposit which is there found in fair thickness over certain tracts, as near Southwold and Halesworth,\* where it underlies the Glacial Drift and overlies the Chillesford Clay. This Suffolk gravel was classed with his Bure Valley Beds by WOOD (or as the base of the Lower Glacial Drift), and was named Westleton Beds by PRESTWICH, but my colleague, MR. H. B. WOODWARD, has taken what seems to be its continuation northward, in Norfolk, to belong to the Crag.† On this subject, however, there is much difference of opinion; but PROF. PRESTWICH has also been led to the conclusion that our Pebble Gravel may be the equivalent of the Westleton Beds.‡

On the whole it is perhaps safer for the present to regard the Pebble Gravel as the oldest Drift of our district, and as a bed of somewhat local occurrence.

PROF. HUGHES has described this bed, in Hertfordshire, as the "Gravel of the Upper Plain," and has said that from its "great extent, persistent character, and uniform level" it probably "must be a marine deposit,"§ a conclusion with which one is

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\* See Memoirs of the Geological Survey. The Geology of Southwold 1887, and The Geology of the Country around Halesworth 1887.

† Memoirs of the Geological Survey. The Geology of the Country around Norwich, 1882, and *Geol. Mag.*, dec. ii. vol. ix. p. 452 (1882).

‡ *Geol. Mag.*, dec. ii. vol. viii. pp. 467, 468 (1881), or *Rep. Brit. Assoc.* 1881, p. 621. (1882).

§ *Quart. Journ. Geol. Soc.*, vol. xxiv. pp. 284, 285. (1868.)

disposed to agree. As yet no fossils have been recorded from the Pebble Gravel.

*Berkshire, Buckinghamshire, Hertfordshire, and Middlesex.*

On the tops of Ashley and Bowsey Hills, the highest parts of the large Tertiary outlier west of Maidenhead, there is a sandy gravel, consisting of flint-pebbles, a few sub-angular flints, and here and there quartz-pebbles. In a pit in the wood at the north-western part of the top of Bowsey Hill, there was, in 1869, a thickness of 5 feet of this gravel in which one green-coated flint (from the Reading Beds) was seen, and a great quantity of small quartz-pebbles, which gave the whole a whitish look.

On the hill-top just above Luxter's, about a mile and a quarter south of Turville, there are two small hillocks of flint-pebbles of various sizes in a loamy matrix. All around is chalk, almost bare, or covered with a little of the usual stiff brown clay with flints.

At Chequer Farm, north of Turville, the highest part of the hill is of gravel, chiefly of flint-pebbles, the greatest depth of which was said to be 16 feet.

At Cadmore End Common, at the north-western end of the Lane End Tertiary outlier, there is gravel with sand.

These three occurrences, however, have not been coloured on the map (Sheet 7, western edge), as Pebble Gravel.

The two summits of the Lane End outlier have small cappings of this deposit.

MR. F. J. BENNETT has noted a section, showing from 3 to 5 feet of pebble-gravel, on the Coleshill Tertiary outlier, near Amersham.

It is only on the main mass of the London Clay, north and north-west of London, that this pebble-gravel occurs in force, beginning on the top of the escarpment in Hertfordshire, and extending southward into Middlesex.

Some small patches, down the slope of the Hertfordshire escarpment, which are probably of later age, have been coloured with this deposit; perhaps these are merely the product of the destruction of a former extension of the old gravel, or of still older Tertiary pebble-beds; perhaps in some cases only a pebbly condition of the Glacial gravel of the lower levels to the north. These doubtful patches may be noticed first.

On the northern flank of the hill a little north of Woodcock Hill Kiln, near Rickmansworth, and below the Tertiary escarpment, there was a pit about 12 feet deep, in an irregular deposit of sand and gravel: the former at top and with layers of gravel in it; the latter composed chiefly of flint-pebbles, but also with angular flints, a few quartz-pebbles and pieces of iron-sandstone, and containing some small masses of the clayey greensand and green-coated flints of the bottom-bed of the Reading Beds. This gravel forms a fairly-marked hillock. In some chalk-wells in the field just north of the kiln I saw some thickness of pebble-gravel lying irregularly on the Chalk.

MR. J. H. BLAKE notes that "near Sandy Lodge, eastward of Moor Park, and near Oxhey Hall, south of Watford, are some small patches of gravel, consisting mostly of black flint-pebbles, evidently derived from older Tertiary beds. In a chalk-pit west of Sandy Lodge some of these pebbles are embedded in clay-with-flints to a depth of 3 feet."

"Similarly derived pebbly gravel occurs also at Watford Heath, south-westward of Bushey, and in the railway-cutting it is shown resting on the Reading Beds."

Going to the higher grounds, it may be open to doubt whether the gravel along the high ground from Woodcock Hill toward Batchworth Heath should not be classed with this rather than with the Glacial gravel. MR. BLAKE describes it as "mostly composed of very small pebbles, but there are some sub-angular flints mixed with sand, loam, and many small quartz-pebbles."

At Batchworth Heath, and in the neighbouring part of Moor Park, there is some sand and gravel.

From the eastern end of Bushey, by Stanmore Heath, and over the top of the ridge to the south, there is a large mass, forming the highest ground in

Middlesex. The late MR. TRENCH, when mapping the Tertiary beds of these parts, noticed that "there is a pebbly brick-earth on the London Clay in many places: thus, near Bentley, W. of Stanmore, there is brick-earth, 12 feet thick, not so sandy as that of the Thames Valley, and which burns to a red brick. The like occurs also westward from Barnet and, with gravel, at Totteridge Green."

On the high ground of Shenley and Ridge, and to the south, is another mass. MR. WOODWARD notes that "traces of pebble gravel occur at Shenley, and at Porters (westward) a labourer said that he had dug 4½ feet deep in gravel, in making ditches round the house."

Of the small tracts north and east of Ridge Hill he says "by Hill Farm and Mims Wood there are patches of gravel, consisting of small pebbles of black flint and of quartz, and probably nowhere more than 2 feet thick."

Of the long mass of Barnet and Hadley, MR. BENNETT notes that "at Barnet a new road-cutting, about the middle of the town, showed 3 feet of coarse iron-coloured sand."

The largest mass of all is that irregular three-limbed sheet ending in Hatfield Park, on the north-west, at Bayford on the north-east, and at Potters Bar on the south. The gravel is shown at Hatfield Park Kiln (see p. 205). MR. TRENCH noted that "on the hills around Little Berkhamstead and Bayford there is gravel, consisting of pebbles in a coarse sandy matrix," and MR. BENNETT records that "a little northward of the Clock House, Potters Bar, there was a good section, to a depth of 7 or 8 feet, the matrix being often clayey."

In a pit in Bencroft Wood by the southern side of the road, nearly 2½ miles west of Broxbourne, sand and gravel occurred; and in the small outlier north of Broxbourne Bury there was a pit in current-bedded pebble-gravel.

A little Pebble Gravel has been found in places on the Bagshot outlier at Hampstead.

### *Essex and Kent.*

It is in Essex that we get this gravel distinctly overlying Bagshot Beds, and this has been seen clearly at High Beech, where, in the reservoir-section, the gravel was exceptionally clayey (see p. 272).

There are many smaller patches just eastward, and at Jacks Hill a mass about 1½ miles long, in which are many shallow pits, or the remains thereof, eastward of the Wake Arms. MR. WOODWARD notes sections showing "2 or 3 feet of fine gravel, resting on loam [the sandy top part of the London Clay], and mostly consisting of quartz-pebbles, though in places with a large number of flint-pebbler, probably derived from Bagshot pebble-beds."

"On the high road half a mile or so southward of the Wake Arms (in a separate patch) there is clayey gravel and sand, to the depth of 3 or 4 feet, which contains many large shattered flints (about 5 per cent. of the whole)."

Eastward of Epping is another collection of thin gravel-cappings, of which MR. WOODWARD contributes the following notes:—

"South of Stonehurst, or about half a mile S.E. of Epping, there is a small capping of pebbly gravel, some 2 or 3 feet thick."

"In the Gaynes Park mass, pits at Mount Quarter showed gravel, chiefly composed of flint pebbles, with some of quartz and some comparatively un-worn flints. Seams of sand and of brick-earth also occur, and the surface is loamy. The whole thickness is about 6 feet."

"South of Cold Hill and of North Weald Station there is a thin gravelly capping, mainly of pebbles of flint and of quartz, on the loamy London Clay."

"In the railway-cutting more than half a mile eastward of the station pebbly gravel, up to 3 feet thick, is passed through."

At the western end of the Bagshot outlier of Havering MR. WOODWARD has mapped a small patch of gravel, of which he remarks that "the Bagshot pebble-beds have been washed over the London Clay in sufficient quantity to be worked. Pebbles of quartzite and of quartz and angular flints also occur, though their number is small in proportion to that of the flint-pebbles." Their occurrence however seems to point to something more than a wash from the Bagshot Beds.

"A trace of gravel, too small to be mapped, occurs on the southern side of the Southweald outlier."

There are some small patches in the neighbourhood of Warley of which MR. WOODWARD notes as follows :—

"A small pit was opened in gravel east of Warley Place."

"A like pebbly gravel occurs from just S.E. of Warley Street to Hill House."

"East of Ellands Wood a large pit showed from 8 to 10 feet of pebbly gravel, the pebbles being mostly of flint but a few of quartz, and there were also some large comparatively unworn flints. This gravel rests on the London Clay, and is evidently derived from the Bagshot pebble-beds. It may be of Post Glacial age, the large flints being perhaps derived from Boulder Clay."

"In Childerditch Wood, a little eastward of the above, it is difficult to trace the extent of the gravel, which may reach northward on to the Bagshot Sand."

"Further eastward, at Lodge Farm, pebbly gravel, like that of Ellands Wood, was shown to a thickness of 8 feet, capped by about 3 feet of gravelly loam."

Of the patch at Laindon, or Langdon, Hill MR. WOODWARD says that it is "an irregular capping of quartzose gravel, like that at High Beech, which has little regard to level. However the greater part of it and of the Bagshot pebble-beds has been carted away."

At Hadleigh a larger mass has been mapped, with smaller patches on other parts of the Bagshot outlier. Of these MR. WOODWARD notes that "at Hollowbone, N.E. of South Benfleet Station, a shallow pit showed 2 feet of subangular flint gravel and sand, with pieces of chert and of sandstone."

"On or near Thundersley Common some pockets of gravel were seen."

"At Hadleigh the best gravel-pits were at Scrub House, to the east, where 5 feet of gravel, consisting both of angular and rounded flints and of chert, was dug."

MR. BRISTOW, in mapping the Bagshot Beds hereabouts, noted that "the table-land between Garretts and Bramblewood, N.E. of Hadleigh, is covered pretty thickly with flint-pebbles, mostly small."

MR. WOODWARD continues that "just south of Rayleigh a mere trace of gravel was seen in one place by the road-side."

"Near the church about 2 feet of ferruginous gravel was seen." In one place, on the eastern side of the road at the edge of the town N.E. of the church, sand and gravel are to be seen cemented by iron-oxide into a hard mass.

There seems to be some doubt as to the classification of these Hadleigh and Rayleigh gravels. So much subangular flint is described as occurring, together with pieces of chert, that one is led to think they should be classed rather with the Plateau Gravel, next to be described, than with the Pebble Gravel. Again the patches of gravel near Hockley (on the same ridge) have been coloured as Glacial. MR. WOODWARD remarks indeed that "the composition of the gravel of Rayleigh and Hockley is rather similar to that of the lower [River] gravels at Southend. It is ferruginous, and composed of rolled and angular fragments of flint and of chert, with plenty of quartz-pebbles about the size of peas."

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At Shooter's Hill there were many sections of pebbly gravel, which have now probably disappeared. MR. GOODCHILD indeed says that "the term gravel applied to this deposit is a decided misnomer; it is a pebble-clay, and not a gravel at all";\* from which I am led to infer that such sections as were open many years ago, and which led me to call the deposit a gravel, do not now exist. My recollection of the hill-top is certainly that it was gravelly, and gravel is marked in seven places on my working map. Moreover MR. J. TRIMMER, a remarkably good observer, notices this as gravel, and that "flints occur in it in different stages of attrition, from the least to the most rolled."†

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\* *Proc. Geol. Assoc.*, vol. ix., no. 3, p. 159. (1885.)

† *Quart. Journ. Geol. Soc.*, vol. ix. p. 292. (1853.)

In the sand (with the gravel) there was sometimes a little clay, and sometimes small pieces of ironstone.

Speaking of a fresh section, MR. GOODCHILD, on p. 160 of the paper above quoted, says that "quite sixty per cent. of the pebbles lay with their longer axes in every direction but the direction they would naturally assume if drifted into their present position by water. A large number were quite on end, and these lay side by side with, and over, and under, others quite in their normal position. A stiff clay matrix with stones of all shapes lying at every imaginable angle throughout the mass looks uncommonly like a deposit of glacial origin." I have however seen a like thing in Bagshot pebble-beds, in Hampshire, and am disposed to credit drag or slip down hill with some amount of stone-moving power.

A year later MR. SPURRELL alluded to this interesting deposit as follows:— "This does not appear to exceed fifty feet in its greatest depth [? much less]. It is formed of yellow sands and sandy clays with layers of gravel. These alternate. On the Eastern side of the hill, sandy layers predominate over gravel, in a section twelve or more feet deep; on the South, clays [? London Clay] underlie a great depth of pebbles; while on the North-West, beds of clayey sand and pebbles are nearly equally laid.\*

There are cappings of pebbly gravel at Badgers Mount, at Mounts Wood and at Telegraph Hill, on the Swanscomb Tertiary outlier.

#### PLATEAU GRAVEL.

Under the above name are included gravels of the ordinary character, that is to say which consist chiefly of subangular flints, though with a varying admixture of pebbles of flint, etc., which occur on high ground, and which cannot with safety be classed either with Glacial Drift on the one hand or with River Drift on the other. In some cases they seem to be the relics of a once extensive sheet, possibly of marine origin. Possibly in our district more gravel ought to have been relegated to this heading than has been. Some of the gravel coloured as Glacial may turn out not to be of that age, and some perhaps that has been coloured as forming a very high terrace of River Gravel may have no right to that alliance.

The question of the classification of sundry isolated patches of gravel is often very troublesome, so that the writer feels no shame in often being able to say no more of gravel than that it is gravel. Under these circumstances it is convenient to have a division to which such doubtful patches can be referred without pledging one's self to any theory. "Where ignorance is bliss 'tis folly to be wise" (or at all events to try to seem so) holds in Drift-classification, as in many other things. As a matter of fact too it is sometimes unimportant what any particular gravel may be; it is enough to know what sort of gravel it is, and where it is. It can be accurately mapped though its age cannot be made out.

Certain small patches of gravel in Essex which are newer than the Boulder Clay, but occur at high levels, and have no relation to the River Drift, are included here; but merely as a matter of convenience. Indeed it is likely that our Plateau Gravel as a whole is newer than the Boulder Clay.

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\* *Rep. West Kent Nat. Hist. Soc.* 1886.

In Berkshire, at the south-western corner of our district, westward of Windsor Park, there are, on the higher tracts of the London Clay, some patches of gravel, which have been coloured on the map (Sheet 7) as River Gravel, or to a less extent, as Glacial (P by a slip).

MR. C. E. HAWKINS, who mapped most of them, agrees with me however that such definite classification of these patches is not safe, and that it might have been better to mass them with the less definite Plateau Gravel.

Of these, which occur near Warfield and Winkfield, MR. HAWKINS has made the following notes :—

“Traces of sand and gravel may be seen in Warfield Churchyard.”

“A pit about a quarter of a mile south of Haley Green, Warfield, showed some 5 feet of sandy gravel, containing black bluish and white pebbles and some subangular flints, beneath which a thickness of 4 or 5 feet of sand was said to have been found.”

“Gravel may be seen on the eastern side of the road leading through Haley Green, close to the high road, and again where the footpath to the church leaves the road. Traces of light-yellow and brown sand are also to be seen here and there.”

“At Breck Hill, S.W. of Winkfield Church, brown gravel, containing pebbles, was seen in ditches along the road, a little south of the stream.”

In Essex MR. WOODWARD and MR. BENNETT have classed some patches of gravel (in Sheet 1, N.W.) under this head, and MR. WOODWARD, who has seen all that district, is by no means indisposed to throw in sundry patches, doubtfully coloured as Glacial, but which seem to overlies the Boulder Clay. The following notes are by those observers :—

“At Tothill, less than two miles west of Greensted, a patch of pebbly gravel occurs, on the Boulder Clay, west of the Mill.”

“In the Avenue leading to Greensted Hall there is a trace of gravel, also over the Boulder Clay.” (H. B. W.)

“At Marden Ash, just south of Chipping Ongar, there is a thin patch of gravel on the Boulder Clay.” (F. J. B.)

“About a mile westward of Navestock Heath there is a trace of pebbly gravel on Boulder Clay.” (H. B. W.)

“At Sidegate, north-west of Blackmore, a pit was seen in the gravel, said to have been 12 feet at the deepest, and consisting of flint-pebbles quartz-pebbles and subangular flints, in rather a dirty matrix, which caused the gravel to bind well.” (F. J. B.)

“North-westward of Norton Mandeville, in a pit, north of Forest Hall Farm, gravel, composed mainly of flint-pebbles, with a few of quartz and some subangular flints, was seen to a depth of 5 feet.” (H. B. W.)

“At Lambourn End, there is a thin irregular scattering of pebbly gravel over the northern part of the Bagshot outlier.” Possibly this may belong therefore to the Pebbly gravel. (F. J. B.)

There are two patches south of Kelvedon Hatch. “Westward of Dudbrook a trace of gravel has been mapped, from the pebbly nature of the soil; and by Abbotswick House, Navestock Side, a thin pebbly gravel, which rests on Boulder Clay, has been worked.” (H. B. W.)

“At Pilgrim’s Hall, north of Southweald Park, there is a small patch of this gravel, on the Bagshot Sand.” (F. J. B.)

“To the south-east of Dagnams (Noak Hill), there is gravel and sand, with both angular and rounded flints and quartz-pebbles, about 4 feet thick, on both Boulder Clay and London Clay.”

“On the high road between Brentwood and Brook Street there is a small patch of pebbly gravel, about 2 feet thick.” (H. B. W.)

Of various patches of gravel further east in Essex (in Sheet 1, N.E.) MR. WOODWARD contributes the following notes, with the general statement that “upon the Boulder Clay there is sometimes an irregular gravelly deposit, of trifling thickness and rarely



worked. Similar deposits occur on the London Clay and then their precise age is not so apparent. They generally have the appearance of a local wash, and as such may be ranked with those Older Post-Glacial Gravels which were formed, according to MR. S. V. WOOD, during emergence after the great Glacial depression. In the neighbourhood of pebbly Bagshot Beds such washes are naturally to be found."

"The gravelly deposit which covers a good deal of ground at Mountnessing is doubtless newer than the Boulder Clay, for it seems to lie indiscriminately on this and on the London Clay [as well as on Glacial gravel]. Generally it is only a foot or 2 feet thick; but just east of the church, where it has been worked, it is 5 or 6 feet thick. It is an angular flint gravel with much loam, and quartz is not common in it. In the churchyard the graves are dug in loamy gravel, and the like is exposed northward near Westlands and Bacons Farm."

"The patch at Stock Thrift, just south of Stock, is very pebbly."

"So also is that at Meephole Wood, eastward of Billericay, where the following succession was shown:—Loam about 3 feet thick, resting on gravel, chiefly of flint-pebbles, and sand, 2 to 3 feet thick, on London Clay."

"At Trueloves, westward of Ingatestone, there is gravel composed of flints, quartz, and quartzite."

"Traces of a like fine subangular flint-gravel, and brick-earth, occur in ditches S. of Howlet's Hall, S.W. of Highwood."

"Near Redindike, southward of Highwood, gravel has been dug."

"At Highwood there is much loamy gravel from east of Love Green to Edney Green, at which last place it was seen resting on London Clay in the roadside, whilst at the Green Man inn it is on Boulder Clay. It is variable in character, pebbly or angular, but seems to have been chiefly derived from the Bagshot Beds, over which it partly extends."

"At Chapel Wood and at Hylands, south-westward of Widford, the Boulder Clay is covered with a gravelly and loamy wash, not enough however to map."

"North of Galleywood Common the Bagshot pebble-beds and loam have been washed down in sufficient thickness to have been worked."

"Northward, near Gravel Hall and about half a mile to the west, two patches of gravel, a foot or so thick, may be traced clearly resting on Boulder Clay; and, from their similar level, two neighbouring patches, at Barrack Lane and at Widford, may safely be ranked with them. Remains of the Mammoth have been found in the sandy subangular flint-gravel at the last place."

## CHAPTER 19. GLACIAL DRIFT.

## GENERAL REMARKS.

We are here but little concerned with the question of the classification of the various deposits that have been grouped together as Glacial Drift, that is to say, deposits which were made at a time when glacial conditions prevailed more or less generally, when our islands were either overridden by an ice-sheet, or were subjected to local glaciation, or were fringed by an icy sea. Our Glacial Drift is simple, as compared with that of districts further north: we have practically but two divisions of it, the upper a mass of clay mostly crowded with glaciated stones of various kinds, the lower a thinner sheet of gravel and sand, with occasional loam, but without evidence of glacial origin.

Under these circumstances it may be asked why is this gravel and sand included with the Glacial Drift. The answer is because it seems to occupy the same position as, and either to be, or once to have been, continuous with other masses of gravel and sand beyond our borders, which, though underlying the great Boulder Clay, are shown to be allied to it by sometimes containing a thinner mass of a like stony clay and by sometimes overlying another Boulder Clay. It seems that the presence of this lower mass of Boulder Clay has not been noticed in our district, and it was with some surprise (if surprise is to be allowed in the case of so varying a formation as Glacial Drift) that I lately saw evidence of its occurrence at our north-eastern boundary, in a new railway-cutting at Maldon (see p. 316).

It should be understood therefore that there is a difference between the term Glacial, used as a proper name for a geologic period, and the ordinary adjective glacial, used merely as signifying the occurrence of very cold, or icy, conditions. The Glacial Drift may contain beds that are not of distinctly glacial origin; but there seems to be no need of using a special word for such, and calling them Interglacial: they are part and parcel of the formation, mere interludes as it were, showing only some slight temporary or local changes.

Again there has been much misunderstanding from the misuse of another term, Preglacial. It has been used, and by geologists of note, simply for beds that are below the Boulder Clay, and has been thus applied, in our own district, to the gravel and sand underlying that clay in Hertfordshire, which is really part of the Glacial Drift (the Middle Glacial of WOOD) quite as much as is the Boulder Clay itself, for reasons above given. The only proper use of the term is for beds which we have reason to infer are older than any certain Glacial Drift, but which, on the other hand, cannot be safely referred to the Crag, or to any older for-

mation. The only case in which the term should be used in our district is for the Pebble Gravel, already described, and perhaps for some part of the Clay-with-flints: it means little else than a confession of ignorance as to the exact geologic whereabouts of the beds to which it is applied. The misuse of the term Pre-Glacial has been pointed out by MR. H. B. WOODWARD.\*

There are difficulties enough in the classification of Drift, without bringing in others that are needless, especially as glacial conditions seem to have begun and to have ended at different times in different tracts, naturally lasting longer in higher and more northerly than in lower and more southerly parts. Moreover neither their beginning nor their ending would be sudden; so that we have no right to expect a sharp demarcation between the Glacial Drift and the formations that, in geologic time, fore-ran or followed it: the base and the top will be taken at different horizons in different districts.

#### GRAVEL AND SAND, with LOAM.

Leaving out of consideration the bed of Boulder Clay at Maldon, above alluded to, which may represent the Lower Glacial of WOOD, the lower member of the Glacial Drift in our district consists of a gravel, for the most part made of subangular flints, with pebbles of flint, of quartz, and of quartzite, whilst occasionally it is a sand. There is also sometimes a mass of loam, or brick-earth, which has been mapped separately, on account of its lithological distinctness. The whole is of no great thickness, nor is it of universal occurrence, the Boulder Clay often overlapping these beds, so as to rest at once on the older Tertiary formations.

From its occurrence as part of a wide-spread sheet one would infer that the gravel, with its associated sand, is of marine origin, and this inference is strengthened by the fact that where fossils have been found in such beds, beneath the Boulder Clay (far beyond our district) they are marine.

This gravel moreover sometimes contains many rolled Jurassic fossils, such as *Gryphæa dilata* and *Belemnites*, that point to transport from distant places, and may be looked on as erratics, in common with the foreign stones of the Boulder Clay; stones of a class too which are sometimes common in the gravel itself.

Although large masses of gravel have been coloured on the map as belonging to the Glacial Drift, and are now described as such, yet we have not got rid of our uncertainties in gravel-classification. Many masses on the west have been so coloured only as a matter of probability: they seem to have once tied-on to gravel that is undoubtedly of Glacial age; but, from the absence of Boulder Clay, one cannot be certain about them. Some of these should go perhaps with the Plateau Gravel, above

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\* *Geol. Mag.*, dec. ii. vol. vi. p. 285. (1879.)

described, as of uncertain age, and some may possibly be only a very high terrace of River Gravel. On the other hand some isolated patches that have been coloured as high terraces of the last may possibly belong to this or to the Plateau Gravel. In such matters the balance of probabilities is our only guide, and our classification must be understood to be only the best that we could make in the absence of good evidence.

*Berkshire and Buckinghamshire west of the Midsbourn.*

In noting the gravels on the high ground westward of Cookham Mr. H. B. WOODWARD says that on the outlier of the Reading Beds westward of Cookham Dean Common "there are two patches of gravel, the one to the south being a mere trace, whilst in that to the north a pit showed 3 feet of sandy gravel, made up of small fragments of quartz, grit-pebbles, and flints, both rounded and subangular."

Of the tract just southward of the Lane End Tertiary outlier Mr. J. H. BLAKE notes that "much pebbly gravel occurs on the Clay-with-flints around Pamoor, and pebbly and subangular gravel intermixed was shown in a section on the side of the road leading from Chisbidge to Chisbidge Cross."

Mr. WOODWARD says that "there is much difficulty in the determination of the relative ages of the gravels bordering the Thames, from Hambledon eastward to above Little Marlow. The gravel, in some of these high masses, seems to thicken toward the river; and some of the patches are on sloping ground, as near Boventon Green and Woods Barn. Some of the gravel seems almost wholly made up of pebbles, as at Highfield Barn and Ridge Wood, west of Hambledon." Possibly therefore these should be coloured as Pebble Gravel.

"A little patch of pebbly gravel and loam occurs at the south-western edge of Dean Garden Wood, S.E. of High Wycombe. Patches of like character may be detected to the south, from the very pebbly nature of the soil, south of Hearty Fine and at Sheepridge Wood."

On the hills west and south of Loudwater there is much gravel, alike over the Chalk and over the outliers of the Reading Beds.

Mr. W. A. E. USSHER notes that "below the bend of the road up the hill just north-east of Loudwater there is, in one part, pinkish brickearth with grey streaks, and brown sandy gravel, made up of subangular flints etc. and pebbles, resting on the Chalk."

Of patches eastward of Penn Mr. C. E. HAWKINS says that "at the extreme north-western corner of Great Wood there was shown, in a shallow road-cutting at the edge of the wood, a patch of mottled brown, white and crimson clayey sand, about 1½ or 2 feet thick, overlain by about 4 feet of gravel."

N., S., and E. of Beaconsfield nearly the whole of the high ground is capped by gravel, so much so that the Tertiary beds are rarely to be seen. Sections of the former have already been noted at pp. 188 and 189, and there are others.

Mr. T. R. POLWHELE noticed that "in a chalk-pit close to Davenies, north of Beaconsfield, gravel and sand rest on an uneven surface of the Chalk, and the cutting at the 25th milestone, on the high road west of that town, shows the Chalk to be capped by brick-earth, clay, sand, and gravel."

Mr. HAWKINS has contributed the following notes, taken in 1869:—"A large pit, on the northern side of the road about 1½ miles west of Beaconsfield, showed brickearth overlying, and in some places overlain by, gravel; the latter being composed mostly of small subangular flints, some green-coated, but with a few pebbles of flint and of quartz. The brickearth was in some places brownish-yellow and sandy, in others brown mottled with white and red."

"A round pit nearly 1½ miles east of Woburn Church was about 20 feet deep in brown gravel."

"Round the pond, marked on the map, nearly a quarter of a mile N.E. of the house at Cliefden there is a thickness of about 4 feet of gravel."

"At the junction of the two roads about a third of a mile north of Dropmore Lodge is a pond, at the western end of which is compact gravel, whilst at the eastern end there is clay (Reading Beds?)."

"At Thorney Wood Kiln, east of Brook End, a pit near the road showed about 5 feet of gravel over about 15 feet of brown and grey bedded brick-earth; whilst another pit, in the wood eastward, showed about 3 feet of gravel over 9 or 10 feet of sharp brown and buff sand, with a few nodules or streaks of clay." [I had, before this, noted the brickearth almost abutting against the gravel, and that mammalian bones, in a much perished state, had been found in it, which is suggestive of its being River Drift.]

"A small pit by the roadside just westward of Starveall (W. of Hedgerley) laid open about 5 feet of red gravel."

Along the road itself, down hill toward Woodlands, gravel with sand is shown in the cutting, and a chalk-well near Starveall proved that there was 15 feet of it over the Reading Beds.

Returning to MR. HAWKINS' notes, "on the northern side of the road, a few yards N.W. of the public house on Culm Green, westward of Hedgerley, a small section showed gravel with layers of red sand. Coarse red sand is also to be seen along the roads a little to the S.E."

"In a garden on the northern side of the road that runs along the north of Broad Oak Wood a small pit, or pond, showed red sand near the bottom."

"At Colly Hill a pit, in a wood N.E. of the house, was about 20 feet deep, in sandy gravel, somewhat bedded, with layers of sand. Patches of the gravel were quite black, and at one place there was mottled clay, probably reconstructed Reading Beds, containing small pebbles and flints. In the same wood there were sand-pits, the sand mostly red and lying apparently in hollows in the clay-escarpment."

At the southern end of Stoke Common a pit, on the eastern side of the road and a third of a mile east of Grooms Place, showed about 12 feet of brown, partly discoloured grey, somewhat bedded, sandy gravel, composed of flints (some green-coated) and pebbles of flint, quartz, quartzite and sandstone.

MR. POLWHELE has noted a neighbouring pit "at West End, about a mile north of Stoke Poges, showing about 15 feet of brick-earth, with layers of small flints and a thin band of black ironstone, capped by gravel."

Of the mass north of Hedgerley MR. HAWKINS has the following notes:—"A pit on the western side of the road west of Helmet showed about 6 feet of pebbly gravel; and another, a little to the north, showed about 10 feet of gravel very full of flint pebbles, bedded, and with layers of red sand. A third pit, at the northern end of the small wood between Helmet and Slade, was 15 feet deep, in gravel and red sand with pebbles; whilst a fourth, at the southern end of the same wood, was over 5 feet deep in the like."

"A pit on the northern side of the road at Hedgerley Green showed 8 feet of gravel composed of pebbles of flint and of quartz and subangular flints, with layers of white and brown sand."

A long mass occurs along the top of the hills on the right side of the Misbourn Valley from a little below Amersham nearly to Denham.

At Frog Hall Kiln the Reading Beds are in part capped by brickearth, gravelly at top, and with gravel alongside, but the relation of the two deposits was not seen.

MR. HAWKINS says that "at the four cross-roads between Asting Wood and Maltmans Green (southward of Chalfont St. Peter) from 12 to 15 feet of gravel, mostly of subangular flints, was seen," and "a pit, about 8 feet deep, near Gerards Cross Common showed white shingly gravel, with a few pebbles of flint, here and there a large pebble of sandstone and of quartz, and a few nearly unworn flints, over a similar gravel apparently without the pebbles of the older rocks."

MR. USSHER notes that "at the junction of the roads about two thirds of a mile north of Fulmer House there is bright red and yellowish mottled

sand, slightly loamy, with a surface-capping of quartz-pebbles and subangular flints."

*Buckinghamshire and Hertfordshire, between the Misbourn and the Gade.*

The high ground between the Misbourn, below Amersham, the Chess, below Flaunden, and the Colne is almost wholly formed of a sheet of gravel, hiding the boundaries of the Tertiary outliers, except at the south, and allowing the Chalk to be seen only along the flanks of the main valleys, and up the dry side-valleys of the Colne, the cutting-back of which has given the gravel a very irregular boundary.

MR. H. B. WOODWARD notes that "by Woodside, N.E. of Amersham, there is a little gravel, and at Old Field, westward of Cheneys, the digging-out of a pond showed gravel, brick-earth, sand and clay-with-flints, all mixed up together. The gravel hereabouts is not thick enough to be of value."

MR. W. A. E. USSHER says that "the gravel on the hills east of the Chalfonts is composed of angular and subangular flints and of pebbles of flint, of quartz and of sandstone, in reddish-brown or grey sand."

"The gravel-pits at the southern part of Charley Wood Common, N.W. of Rickmansworth, gave the following section, the gravel being loamy in one pit," :—

Brownish-red sandy gravel, of flint pebbles, with a few subangular flints and quartz pebbles.

Brownish-red and grey mottled sand.

Gravel, as above.

Grey and reddish mottled sand.

MR. J. H. BLAKE also notes that "gravel and mottled red and brown clay occur at the eastern corner of the Common," and an older note of my own marks the occurrence of a little loam with the gravel here.

MR. J. RHODES, Fossil-collector to the Survey, noted the cutting, on the Metropolitan Extension Railway, eastward of Rickmansworth Station, as follows :—

Bedded gravel and sand ; 10 to 16 feet.

Chalk with nodular and tabular flints. Rubbly, and with large pockets of flint and clay down to the level of the line. Fossils few. 12 feet.

'On the hills southward and westward of Berkhamstead there is a little gravel, as also, to the east, on the other side of the valley.

According to MR. WOODWARD "a very loamy gravel occurs north and east of the Tyler's Hill Tertiary outlier, east of Chesham, and nearly all round this the soil is very pebbly, though sometimes there is not enough gravel to justify its being mapped."

The great mass of gravel however between the Chess and the Gade is from below Cheneys, on the former river, and below Kings Langley, on the latter, over which tract the high grounds are wholly gravel-capped, the gravel being very pebbly towards the Gade.

MR. J. H. BLAKE notes that "in the neighbourhood of Red Hall and Red Heath, northward of Rickmansworth, the gravel is mixed with loam and contains many pebbles of quartz."

MR. J. RHODES records the railway-cutting at Croxley Hall, east of Rickmansworth, as in 12 feet of bedded gravel and sand ; overlying Chalk, seen to 12 feet, with layers of nodular flints and fossils.

*Hertfordshire, between the Gade and the Ver.*

MR. WOODWARD observes that "between Maiden Crouch and Potters Crouch, some two miles W.S.W. of St. Albans, a gravelly deposit occurs toward the brow of the hill. By Tenements about a mile N.E. of Abbot's Langley, there is a little gravel resting on loam."

From Abbot's Langley, on the west, and Park Street, on the east, to the junction of the marshes of the Gade and of the Colne, on the south, a sheet of gravel takes up by far the greater part of the surface, being capped by Boulder Clay, or sometimes by loam, on the north, and the Chalk being seen hardly anywhere but along the flanks of the valleys, indeed not always then. It is noteworthy that in the gravel around Watford there are very many pebbles of quartz-rock and of quartz (from the New Red Conglomerate), often of large size.

MR. WOODWARD notes that "gravel may be seen near Burston's Farm, west of Park Street; and by the high road about a mile S.W. a pit showed gravel, with beds of sand, in pipes, the gravel being composed of pebbles of flint, small ones of quartz and of grit, and subangular flints, some little worn."

PROF. PRESTWICH, who was the first to notice the occurrence of Boulder Clay along the railway here, has said:—

"A ballast-pit has recently been opened at the Watford end of the Bricket Wood cutting, and immediately south of the line, which exposes a section of much interest. The Boulder Clay has there almost thinned out, leaving but a seam one to two feet thick, whilst both above and below it is a thick bed of gravel. The lower sandy gravel, which consists chiefly of sub-angular flints and flint pebbles, with some quartz, sandstone, and old-rock pebbles, with subordinate seams of whitish sand, has a clean, washed appearance. The upper gravel consists of very similar sub-angular materials, but is less sandy and darker. . . . The upper gravel seems to be of limited extent, but the lower gravel I believe to pass under the Boulder Clay, for there is an old pit of [in] the same gravel near the brook on the north side of Bricket Wood, towards the Watford end. There is no Boulder Clay in this other pit, but the gravel presents the peculiarity of being concreted in places into large . . . masses by a calcareous cement. In this pit I found no organic remains, but in the ballast pit I was fortunate enough to discover, in the lower gravel, a few pieces (but not sufficient to determine the species) of the tooth and tusk of an elephant. A workman . . . told me he had found several bones in the lower part of the gravel. . . . The lower gravel reposes upon an irregular surface of chalk, which is exposed in places at the bottom of the pit . . . now no longer worked."\* From the occurrence of gravel both over and under Boulder Clay, one is led to think that the clay in question may be a thin bed in the Glacial gravel, rather than the edge of the main clay, capped by a later gravel. The following remark on the Bricket Wood cutting is from MR. TRENCH's note-book:—"There is here a large development of brick-earth, consisting of light-brown sand and clay with bands of race."

A thickness of 12 feet of gravel was shown in a pit in the small side-valley above Waterside; and in the next side-valley (west of Bricket Wood Common) there were also some pits.

A fine section, showing the very irregular junction of the gravel and the Chalk, occurs in the cutting on the London and North Western Railway southward from the tunnel-mouth, north of Watford, and a shorter one at the cutting north of the tunnel, near Langley Station.

MR. BLAKE, who visited the spot when the excavations on the site of the Orphan Asylum east of Watford Station were being made, in 1869, records "18½ feet of sand, with a little gravel intermixed; whilst in the road, a little to the south and lower, chiefly gravel is exposed, to a depth of about 16 feet, interbedded with sand."

\* *Geologist*, vol. i. p. 242. (1858.)

"In a large pit close to Watford Workhouse from 20 to 30 feet of gravel was seen, resting on the Chalk."

"In another large pit, near the bend in the high road south of Cassiobury House, a thickness of about 12 feet of gravel was seen. Ferruginous sandstone, quartz, grit and other rocks occur with the flints."

In making the railway between Watford and Rickmansworth (in 1862) an irregular junction of the gravel and the Chalk was shown in the cutting at the former town, and also in the larger one at Bright Wells. At the eastern end of the latter the gravel is 15 feet or more thick, and there is often sand at its base: westward, where the cutting is shallower, it is more clayey and the Chalk rises rather higher. MR. BLAKE makes the gravel here "from 20 to 30 feet thick," and adds that "a thickness of about 15 feet of gravel was seen, above chalk, in a neighbouring pit, by the corner of the road N.W. of Bright Wells."

In the next cutting to the west, which is long but shallow, the Chalk is touched here and there, through the gravel.

### *Hertfordshire, east of the Ver and of the Colne.*

MR. WOODWARD remarks that "the northern part of St. Albans, from near St. Peter's Church to Bernard Heath, is on a gravelly deposit, consisting of pebbly gravel, sand and loam, with a doubtful boundary, and which is only provisionally classed as Glacial."

MR. A. G. CAMERON adds (1887) that "at the Workhouse gravel-pits, just at the edge of Sheet 7 of the map, there is a good deal of conglomerate (blocks of pudding-stone) so mixed with the Drift as to make it impossible, until the pits are deepened, to say whether it is in place or not; but the mode of its occurrence shows at least that it has not been moved far." Perhaps it is merely a broken-up bed from the Reading Beds of the small outlier here.

The cutting on the railway to Hatfield, by the London Road, is at first in clay, with flints and pebbles, over chalk with flints (one layer of flints being well marked, and in parts a second also). At the north-eastern end, however, there is a long hollow of brown pebbly gravel, mostly sandy, in parts loamy, and with lenticular masses of sand. The road-cutting just beyond gives an irregular junction-section of gravel and chalk.

The great gravel-mass is eastward of the Ver, from St. Albans to Colney Street, and it reaches across the Colne toward the Tertiary escarpment, largely capped by loam or Boulder Clay. Of this mass MR. WOODWARD sends the following notes:—

"Good sections may be seen by Cunningham Hill and S.W. of Mile House near St. Albans. Subangular flints form the bulk of this gravel, but there are also pebbles of flint and of quartz and a few large unworn flints."

"Gravel has been largely dug by the Midland Railway near Colney Street. It is a sandy flint-gravel, with patches of clay and of brickearth. False bedding was shown in some finely bedded sand."

"A little west of London Colney gravel has been pierced, to a depth of about 15 feet, in sinking for chalk, the junction being irregular. The gravel is sandy in places, loamy in others, and contains pebbles of older rocks, besides the usual flints."

"A little north of the church at Shenley Bury, a mile south of London Colney, a pit showed sandy gravel, composed chiefly of small pebbles of quartz and of flint, and containing some patches of loam. Hence north-eastward the gravel occurs over a fair-sized area, to Colney Heath."

"Up the narrow outcrop of the little valley west of Park Gate, cut through the Boulder Clay, the gravel is rather fine, where seen in section north-westward of Hill End. It has many pebbles and a good deal of sand."

"Between Row Stock and Walltraps gravel was worked, at a somewhat higher level than the main mass to the west."

Over the tract just described (east of the Ver) the gravel is often capped by loam, to the description of which we may now turn.



The cutting on the railway to Hatfield, half a mile south of Beaumont's Farm, is in loam and brown and grey clay, with flints and other stones (P decomposed Boulder Clay). At the bridge, for the road over the line, and eastward, there is coarse brown sand and gravel below, rising gradually at first and then sinking suddenly. PROF. HUGHES noticed that a few of the flints in the gravel had preserved some of their colouring-matter (from the green bottom-bed of the Reading Series).

The next cutting, just eastward, is shallow and in brown clay with a few pebbles etc. PROF. HUGHES noticed here an irregular junction of the clay with underlying gravel.

MR. WOODWARD remarks that "around Camp House, east of St. Albans there are many pits in the brick-earth, in some places with sprinklings of gravel. At Sell Barns, to the south, the deposit is not now worked; but it is probably in sufficient quantity and of good quality in most places, though very pebbly in others.

The sides of the cutting on the Midland Railway south of St. Albans, and between Hedges and New House Farms, were not clear when I saw it, in 1869, but nearly the whole of the cutting could be seen to be in loam, gravelly at top, brown and in parts red-mottled, and sometimes almost a clay. About the middle of the cutting, there nearly 15 feet deep, a boss of gravel rises up suddenly nearly to the top, but on the western side only, and then but for a few yards. This gravel consists chiefly of pebbles of flint and quartz and of subangular flints. MR. WOODWARD noted pebbles of Carboniferous rock and of quartz in the gravelly brickearth. A like brown clayey loam occurs in the shallow cutting that forks westward from this.

The shallow railway-cutting near Springfield Station (Hatfield line) is in gravel with a thin capping of brown loam, which latter alone occurs at the eastern end.

The cutting southward of Nast Hyde is about four feet deep, in the loam, with something like Boulder Clay peeping up at the eastern end.

Westward of Row Green is another shallow-cutting in the loam, with gravel beneath at the south-western end. Of this part MR. WOODWARD says that "patches of loam and laminated brick-earth occur resting on and, in some places, interbedded with the gravel (as by Row Hyde and Nast Hyde)."

"The loam mapped eastward of Colney Street is of no economic value as brick-earth, and may be merely the result of down wash from the Tertiary hills to the south."

Of the strip coloured as Glacial gravel along the valley west and south of Hatfield Park, the same observer notes that "it follows the course of the little stream, and is partially concealed by a little loam. On the west loam has been mapped, and was seen in the railway-cutting, by the 16th mile-post. Its western boundary is obscure, and so it has been ended off against the spur of the Reading Beds, from the downwash of which the loam may have come. Below Welham Green there are in places great masses of pebbles in the gravel, with the longer axis vertical. Where this gravel ends and the River Gravel of North Mims begins is doubtful. It seems likely that the gravel once spread some way over the Tertiary beds, to the south; for by Sheepstead Hall and towards Hawks Head there is a gravelly and loamy soil, with here and there a trace of gravel; but too irregular and indefinite to be mapped."

"North Mims Church is at a higher level than the gravel of the valley, which seems to be a River Gravel. Many pieces of pudding-stone have been turned up in the graveyards."

Turning now to some masses of gravel between the combined Colne and Ver and the Tertiary escarpment, MR. WOODWARD supplies the following note of the patch at New Organ Hall:—"On the hill east of Radlet Station (Midland Railway) large pits were opened in 1868, and connected with the railway. The greatest thickness of the Drift cannot be more than 20 feet. Gravel, loam, and a good deal of fine sand all occur, very irregularly associated and resting unevenly on clays of the Reading Beds. The beds are much contorted, and bent into sharp folds. The sand shows false bedding, and in the gravel there are pebbles of flint, quartz, grit, trap, &c., pieces of chert, and a few large unworn flints, subangular flints being the chief constituent. In the park close by, and just above the Hall, pits showed 8 or 10 feet of sandy gravel."

In a gravel-pit between Radlets and Batler's Green, east of Aldenham, there was a thickness of six or seven feet of loam, with pebbles of flint, quartz and quartzite, in parts more sandy and a regular gravel; and in another pit about half a mile S.S.W. of Newland the gravel, of like pebbles and also sub-angular flints, was 12 feet thick, the lower part being lighter in colour and more sandy.

The shallow cutting on the Metropolitan Extension Railway west of Sandy Lodge, and east of Moor Park, was noted by Mr. J. RHODES, as showing pebbly gravel over Chalk, and a ballast-pit, by the side of the line 100 yards S.E., as showing 12 feet of like gravel on a chalk floor.

MR. BLAKE notes "a good section of gravel on the high road by the side of Moor Park, and S.E. of Rickmansworth Church, where pebbles and sub-angular flints with sand make up the deposit."

In a chalk-pit just north of Bushey Railway Station there is a peculiar clay above the Chalk, to which my attention was first drawn by my colleague the late Mr. TRENCH. The section was as follows:—

Ochreous sandy gravel, partly in pipes.

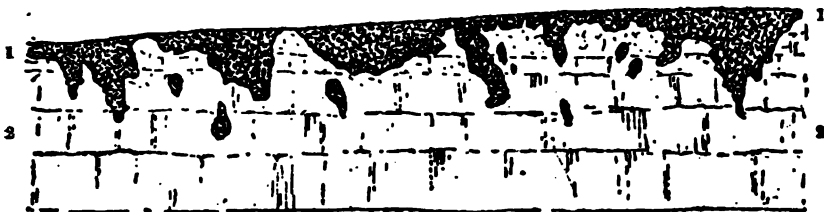
Clay, bluish-grey at top, the rest light-grey; with a three-inch layer of a claret-colour at the base. "A marly clay without sand, which burns to a white brick," according to Mr. Trench's note-book.

Chalk-with-flints. The junction with the clay even.

### *Middlesex.*

The mass that caps the Tertiary beds from Harefield northward, and in places crosses over them to the Chalk was noticed long ago by PROF. PRESTWICH as follows:—"the chalk is capped at the highest points by a thick bed of ochreous flint-gravel, with pebbles of the older rocks. This gravel here occupies a nearly level plane on the hills, and is distinct from the gravel which occupies the adjacent valleys."\*

Figure 47. Diagram Section at the Chalk Pit N.N.W. of Harefield.



1. Gravel, with loam, sand, &c.

2. Chalk-with-flints..

The large chalk-pit more than a mile N.N.W. of Harefield gives a section that is second to none for illustrating the formation of pipes, and of irregular surfaces at the junction of permeable beds with the Chalk. Figure 47 is reduced, about a half, from a sketch of the northern part of the chief face, parallel to the valley, made from the northern end, with some additions from a track cut along the top. This sketch was taken only to show the wonderfully irregular junction of the Glacial gravel, &c. with the Chalk as it appeared in August 1887, and of this it may claim to be a fair general representation: nothing but a photograph could show the endless detail.

\* *Quart. Journ. Geol. Soc.*, vol. xi. p. 81. (1855.)

The pipes are filled not only with gravel, but also with loam, sand and clay-with-flints; some contain also a little mottled plastic clay and masses of flint pebbles, and the beds are sometimes vertical, or nearly so, the lining of the pipes being generally of clay-with-flints. Clearly the contents are a mixture of Glacial gravel and Reading Beds, with a growth of clay-with-flints over the surface of the Chalk. The isolation, on the face of the pit, of parts of slanting pipes, giving the appearance of included masses of Drift in the Chalk is noteworthy.

MR. J. A. BROWN of Ealing, a careful recorder in his district, has at various times described the sections shown in making the reservoirs of the Grand Junction Water Company at The Mount, on the high ground north-east of Castlebar Hill, and from his accounts the following details are taken:—\*

The smaller and more southerly reservoir, at the top of the hill, showed the succession below:—

Soil, very full of stones.

Very pebbly gravel, with various stones and lumps of clay; not a continuous mass, but filling irregular jagged channels, 4 or 5 feet deep, and some probably up to 150 feet long, with a general direction from N.E. to S.W.

Mottled clay, with occasional thin layers of sand; 3 or 4 feet, pressed laterally where cut through by the gravel-furrows.

Buff laminated loamy or sandy clay and sand, with the bedding-planes bent and squeezed under the gravel-channels; dips slightly to the south.

Loamy clay, with sandy layers, more clayey below, evenly bedded, with mica, some ferruginous concretions and masses of Sarsen stone; to a depth of 10 feet from the surface.

Loamy clay, with small scales of mica; proved to a further 10 feet, by trial-borings.

The northern and larger reservoir, separated from the other only by a road, is at a rather lower level, and showed like beds. The channels of gravel go for as much as 500 feet down hill, from the road, whilst lower down, away from them, the laminated beds are parallel and regular, instead of being bent. MR. BROWN gives a figure of a continuous mass of gravel (presumably at the northern part of the reservoir) nearly 50 feet long, 18 wide, and on an average 4 deep, which had been temporarily left standing in the excavation, and which was much larger before being cut off by the workmen; this figure shows a very irregular junction of the gravel with the laminated clayey beds beneath. These laminated beds dipped slightly northward, down the hill, and they are said to lie unconformably (perhaps unevenly would be a safer word) on the undoubted London Clay, though thicker on the hill-top (? 35 to 40 feet) and disappearing a little way below the reservoir.

I did not see the section in the southern reservoir, but the northern one I had the advantage of visiting with MR. BROWN, and of seeing some of the gravel furrows. Whilst allowing that this gravel is probably Glacial, one may feel some doubt about the laminated beds below. We may dismiss the notion that they can belong to the Bagshot Beds, which MR. BROWN has shown to be untenable; but may perhaps fall back on the possibility of their being rather sandy beds in the London Clay. Against this however is the fact that blocks of Sarsen stone have been found in them, an occurrence not yet recorded from London Clay. Is it possible that at the time when the gravel was deposited these loamy beds may have been in so pasty a state, from continued wetness, that heavy stones could sink through them?

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\* *Proc. Geol. Assoc.*, vol. viii., no. 3, p. 173. (1883.) *Trans. Assoc. Municipal Sanitary Eng.* (1884.) *Quart. Journ. Geol. Soc.*, vol. xlii. p. 192. (1886.) Palaeolithic Man in Middlesex, 8vo. Lond. (1887.) *Proc. Geol. Assoc.*, vol. x., no. 4, p. 172. (1888.)

The deposit seems of an exceptional kind, unlike any Glacial Drift in the neighbourhood on the one hand, and on the other differing from what one would expect to find in the London Clay of that horizon. It is to be hoped that further evidence may turn up, and that Mr. Brown may record it.

The occurrence over the surface of the hill-top, of a great variety of foreign stones, of which Mr. BROWN has made a large collection, is suggestive of the former presence of Boulder Clay, since lost by denudation, and this would help to account for the squeezing of some of the beds, which seems to have been done by a force acting from above, and probably therefore of glacial character.

Of the gravel capping Dollis Hill, eastward of Kingsbury, Mr. J. L. LOBLEY says that it consists "chiefly of sand, with flint pebbles, a minority being unbroken . . . and a majority broken. From an examination . . . of 675 stones it was found that 198 were unbroken, 476 broken, and only one proved to be of quartz."\*

Mr. H. B. WOODWARD remarks that "the patch at Hendon spreads over a somewhat larger area than was originally shown on the map. I am indebted to Dr. H. HICKS for drawing attention to the sections here, and for kindly showing me some of them." At a later date I had myself the advantage of visiting Hendon, under Dr. HICKS' guidance, and of making an extension of the gravel-boundary southward. Those parts of the following description between inverted commas are from Mr. Woodward's notes.

"Excavations of later date than the Geological Survey Map, made for new houses, have shown that the Drift here is composed of two beds of gravel, separated by an irregular mass of clay, often very like London Clay. To the occurrence of this clay Hendon owes the purity of its water-supply, for the lower bed of gravel and sand yields an abundant supply of good water, which is separated from the surface-water and from drainage by the overlying clay. This clay is burnt for ballast. A like bed occurs at Finchley." Whether the above-described happy state of things will last when buildings increase greatly may be doubtful.

"East of the church sandy brickearth has been worked, to the depth of 6 feet, resting on sand and gravel."

"At Parsons Street a well was dug through 25 feet of Drift."

On the northern side of Bell Lane, S.E. of the Congregational Chapel, brown clay occurs, but gravel and sand have been found below.

"At the back of the Post Office (Brent Street) the following beds have been worked:—

Gravelly clay, called "Callow"; 5 feet.

Gravel and sand, of irregular thickness, with beds of shingle; 8 or 9 feet.

"Owing to the influx of water the London Clay was not reached."

By the side of Brent Street, just south of White House, Dr. HICKS saw about 8 feet of clay over sand and gravel.

At the southern end of the outlier, more than three quarters of a mile south of the church, there are old overgrown pits.

Mr. WOODWARD remarks that "there is gravel near Frith Manor, on the eastern slope of Mill Hill, which has not been shown on the map."

The mass of Glacial Drift reaching from Finchley, on the west, to Whetstone, on the north, and to Colney Hatch and Muswell Hill, on the east, is one of great interest, on account of the good sections that have been opened in it, of the fact that a sheet of Boulder Clay clearly overlies the gravel, and of its being the nearest to London of any such occurrence.

Mr. WOODWARD remarks that "the gravels which underlie the Boulder Clay here, and which occur also eastward and at Hendon, are of a different kind from those pebble-gravels that cap the higher grounds to the north &c. (see p. 290) They are of more angular character: they contain a few, or sometimes many, pebbles of flint and of quartz; but they have also a great many

\* *Proc. Geol. Assoc.*, vol. x., no. 4, p. 150. (1888.)

subangular flints, a few blocks of granitic and of trappean rocks, and rolled blocks of pudding-stone."

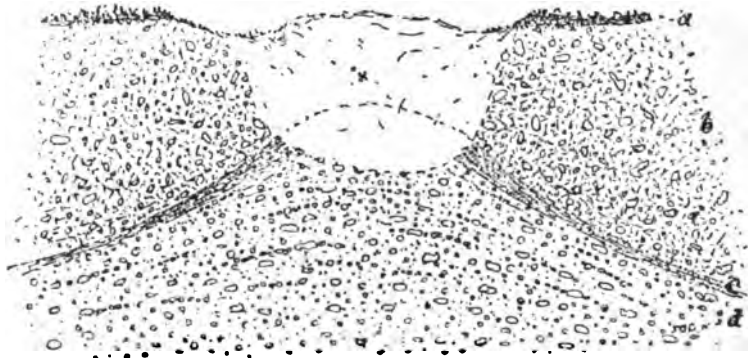
The Drift here was noticed many years ago, before the existence of the Geological Survey, and MR. E. SPENCER described its extension from Muswell Hill to Finchley Common, though he did not trace it to the west and north, noticed the succession of deposits, and suggested "that the current of water which brought the materials of the upper bed [Boulder Clay] into their present situation flowed from the north."\*

It was well known to my old friend the late MR. WETHERELL, of Highgate, of whose collection from the Drift another old friend, the late PROF. MORRIS, has said "The gravel beds of Finchley . . . have yielded to the researches of Mr. N. T. Wetherell . . . many specimens of Flints containing fossils of the Chalk . . . but with these it is important to notice there are sometimes found silicified specimens of *Venericardia* [*Cardita*] *planicosta*, a condition in which these shells are rarely found in their original Eocene beds."†

In later years MR. H. WALKER has brought the Finchley sections to public notice on various occasions.‡ However in speaking of the Drift at Finchley as "unmapped," in his first paper, read to the Geologists' Association in 1871, he was unwittingly in error; for the Drift Edition of the Geological Survey Map was published in that very month, the actual mapping having been finished in 1870. Moreover my notes of some of the railway-cuttings were taken in 1864, 65, rather more than the "three years ago" (= 1868) that he speaks of, the earlier cuttings probably not having been seen by him. MR. WALKER was nevertheless right in saying that public attention had not been drawn to the fact of these sections being open, and he was also right in enforcing the subject on the attention of London geologists. So well indeed did he do this that no one else wrote about it, his industry making any attempt at competition useless.

MR. WALKER mentions a section at Whetstone gravel-pits, in rear of the Swan Inn, where a pocket of Boulder Clay, overlies gravel, which is nearly 20 feet thick. Of this MESSRS. WOODWARD and BENNETT say "a small pit, on the western side of the high road S. of Whetstone showed Boulder Clay scooping into the fine quartzose gravel and sand below, the top 2 feet of the clay being dark brown, with a few purplish spots, and tolerably free from stones, whilst the rest was very chalky." This difference is the result of dissolution of the contained chalk and of oxidation of the colouring-matter. Fig. 48 is from a sketch made by MR. GOODCHILD.

Figure 48. Section at the Northern End of Finchley.



- a. Soil.
- b. Boulder Clay with a trace of lamination at the base, where it passes down into c.
- c. Thin loam, passing down into d.
- d. Sand and gravel.

\* *Proc. Geol. Soc.*, vol. ii., no. 40, p. 181. (1835.)

† *Geol. Mag.*, vol. v. p. 411. (1868.)

‡ *Proc. Geol. Assoc.*, vol. ii., no. 7, pp. 289-298. (1872.) "The Glacial Drifts of Muswell Hill and Finchley," pp. 24, London, 1874, etc.

The cutting on the London and Edgware Railway at the Finchley Station (Church End) gave a fine section of the Glacial Drift, which I examined during the construction of the railway (1864, 1865). The north-western end, beyond the high road, was the clearest part, and showed the following succession of beds:—

Section of an old pond in the Boulder Clay (on the north-eastern side).

Glacial Drift.	{	Blue Boulder Clay, full of stones of various kinds (hard chalk well scratched being most plentiful, and then perhaps Lias limestone).
		Brown clay: by the road 17 feet thick, blue-mottled and with much race; further N.W. with less race, thinner, chocolate-coloured and somewhat like London Clay; still further this bed thins out altogether, and at the north-western end of the cutting the Boulder Clay rests on the gravel.
		Sand and sandy gravel (largely composed of flint-pebbles). This bed was dug for ballast at the north-western end of the cutting, was there 8 to 10 feet thick, and rested irregularly on the bed below.

London Clay; the uppermost foot or more discoloured brown, the rest dark bluish-grey. Much water thrown out at the junction. DR. H. HICKS has a few fossils from this clay.

At and on the other side of the high road the beds were very irregular and the cutting less clear, so that no very definite order could be made out: there seemed to be at one part some coarse clayey gravel or gravelly clay over blue Boulder Clay; at another part there was the following succession, which seems to give evidence of a bed of Boulder Clay in the gravel:—

Boulder Clay.

Gravel.

Brown clay, in parts with buff sand, and passing down into grey clay with pieces of chalk &c.

Mr. Walker's description\* seems to have been taken at a later date than that above given, and as his details differ from those seen by myself (referring to the part eastward of the bridge, which I saw less clearly) it will be well to reproduce them. He says that "at Finchley Station and a little beyond [W.], the cutting reaches its greatest depth. In the rear of the passenger platform on the "up" side of the line the slope is being cut back in order to widen the railway, and it is here that the new section is to be seen." This "extends for about 150 yards on the station side of the railway bridge, at an average depth of about from thirty to thirty-five feet; it is continued beyond [W. of] the bridge for about the same distance . . . the most varied . . . aspects of the beds are on the London side of the bridge." The "beds opposite the railway station are as follows":—

Soil, 6 inches.

Brown sandy clay, with *Belemnites*, *Gryphæa incurva* in abundance, and chalk detritus [? weathered Boulder Clay]; 14 feet.

Dark blue clay, with abundant chalk pebbles, flints, and Liassic and Oxfordian fossils, especially *Gryphæa dilatata*; seen to 16 feet.

"Further on towards the railway bridge the London Clay rises to the surface, and the section presents the following features":—

Soil, 6 inches.

Brown sandy clay, as before, base irregular; 20 to 30 feet.

Thin seam of gravel at intervals.

Brown London Clay, largely re-deposited, with pot-holes filled from the overlying beds.

Just south-westward of the first section the "blue clay is seen to be interbedded with a thick seam of dry running sand, which lies in [or rather like] a dyke in the clay."

At the brickyard (marked "Gravel Pit" on the six-inch Ordnance Map) on the western side of the road about half a mile south-west of the Railway

\* *Proc. Geol. Assoc.*, vol. ii. pp. 290, 291.

Station, the section seems to have varied at different times. In 1870 Mr. WOODWARD noted it as follows :—

Glacial Drift. { Irregular gravelly deposit; 1 to 2 feet.  
Stiff brown clay, with but little chalk and few stones [? Boulder Clay].  
Gravel.

Stiff slate-coloured London Clay.

In 1877 however he noted the following details, between the gravel-top and the London Clay :—

Brickearth and sand, laminated in places and slightly clayey; 20 to 25 feet.  
Pebbly gravel and sand; 3 to 8 feet.

Some years later I noted the following beds, on the northern side of the yard, far from the road :—

Coarse flint gravel, thin.

Brown clay, thin.

Sand, thick, and rising up in a lump in one place.

Gravel, said to have been found below (14 feet).

London Clay, said to have been touched in a well, close by, at 38 feet.

On the southern side of the yard the sand seemed to be replaced by brown loam.

At the same date a pit just north of Oldershill Lodge, or over a third of a mile S.W. of the church, gave the section below, the lower part being hidden by talus; but London Clay being seen at the bottom :—

Thin irregular clay.

Very pebbly gravel.

Clayey sand, with a thin black clayey layer.

MR. WALKER says "In Ballards Lane, leading to Hendon, the pits show in some cases nearly thirty feet of sand and gravel." This must refer to the pits along Hendon Lane, in one of which, just north of a new road towards Hendon Hall, there is brown clay above.

The same author records that gravel has been worked by the high road, near the Green Man Inn, and MR. WOODWARD notes that the adjoining Islington and St. Pancras Cemeteries "are on Boulder Clay, gravel, and London Clay, all three of which are turned out of graves in various parts."

MR. WALKER mentions that the junction of the gravel with the overlying Boulder Clay had been seen "at a ballast-pit in the Hogmarket."

In making the cutting at the East End Railway Station, a small pit was dug at the southern end (near where the station now is), below the level of the line, and this gave the following section :—

Boulder Clay; 6 or 7 feet.

Bedded sandy gravel, largely of flint pebbles; about 10 feet.

London Clay.

The section "at the gravel-pits in the lane leading from Muswell Hill to Colney Hatch," given by Mr. Spencer, in 1835 (see p. 310), was as follows, the separation of the gravel and the Boulder Clay being well-defined :—

Soil.

Marl [Boulder Clay] with waterworn fragments of various rocks, the most abundant being chalk, in such quantity as to give the whole a chalky character. Flints sufficiently numerous to be extracted for repairing the roads; about 14 feet.

Red gravel, of rounded flints and sand; about 6 feet.

London Clay.

A MS. section of Mr. Wetherell's, showing the following order of the beds at the Muswell Hill gravel-pit, now filled up, may be a later version of the above :—

Boulder-deposit, with fossils of various formations, lying irregularly on the bed below, and sometimes filling pipes that extend through the latter; 15 to 20 feet.

Laminated brick-earth; 3 to 4 feet.

Gravel. (Thickness and composition not given.)

London Clay.

These pits are now filled up, being in the grounds of the Alexandra Palace.

MR. WOODWARD notes that "northward and north-westward of Fortune Hill (or Temple Fortune), and about a mile south of Finchley church, there is a patch of sand, with a little gravel, fast being worked out: in fact but a trace remains."

From Southgate a mass of gravel occurs over the high ground northward, for more than 3 miles, sending out easterly spurs, and with an irregular boundary. It has some small cappings of Boulder Clay.

At Bush Hill, south of Enfield, there is fine sandy gravel and sand.

*Essex, Western and Southern Tracts.*

Eastward and north-eastward of Waltham Abbey is a set of very small patches of Glacial gravel, on the London Clay.

At the most northerly of these, a little northward of a farm called Claybury, there was, in 1867, a small shallow pit in a sort of gravelly deposit, a loam full of flints and pebbles, some of the flints very large, but with their edges worn, and some of them much pounded.

There are several patches bordering the right bank of the Roding, and near Chipping Ongar the valley-bottom is mostly in this gravel, which continues in a narrow strip up the tributary to High Laver.

At Higham Hall Brickyard, Oak Hill, Woodford, there is London Clay at the bottom of the pit, but at top an irregular capping of brown and grey clay full of flint pebbles, and in parts underlain by gravel. ? Can the pale bluish-grey clay be Boulder Clay.

The like was shown in shallow pits at the nearer part of the Woodford Hall estate, at the southern edge of which however a deep channel showed (in 1867) 15 feet of bedded sandy gravel, with London Clay rising up nearly to the surface in some parts. In a branch-cut the latter rose straight up from the gravel for about three yards, and in another cut there was much sand, mostly fine. The gravel here consists chiefly of flint-pebbles, but there are also a good many subangular flints (a few green-coated) and some pieces of weathered sandstone.

MR. F. J. BENNETT records "irregular gravel in the railway-cutting north-eastward of Loughton Station, whence it extends northward for more than half a mile."

"In the cutting W.S.W. of Chigwell Lane Station like gravel occurs, and extends northward to Loughton Hall Farm, and eastward."

MR. WOODWARD notes that "in the railway-cutting about a mile W.S.W. of Theydon Bois an irregular patch of gravel may be seen, to the thickness of about 4 feet, in pockets, on London Clay. It is composed chiefly of pebbles of flint and of quartz, with some subangular flints."

At Theydon Mount, about half a mile S.E. of Hill Hall, MR. BENNETT saw "Boulder Clay, overlying pebbly gravel, some 6 feet thick."

At Stapleford Tawney MR. WOODWARD recorded "about a foot of gravel, composed chiefly of pebbles of flint and of quartz, a little way S.W. of the Rectory." This seems to have been too small to map.

Again "traces of pebbly gravel are found westward of the Rectory at Stanford Rivers, and a little sand was dug at the church."

MR. BENNETT notes "a pit south of the Ongar Union House, at Stanford Rivers, which showed about 6 feet of rather coarse subangular gravel, with few pebbles."

MR. WOODWARD contributes the following account of gravel in the neighbourhood of Chipping Ongar:—

"The irregular distribution of the gravel beneath the Boulder Clay is well-marked around Greensted. At Newhouse, south-westward of the church, there are pits in sandy pebbly gravel, those to the west showing Boulder Clay above."



"South of the church gravel has again been dug beneath Boulder Clay." PROF. DAWKINS describes the gravel as composed of flints interbedded with red sand, to a depth of 7 feet.

"Above Greensted Wood the gravel, dug to a depth of 4 feet, is mainly composed of flint-pebbles, with a few of quartz, and towards Hall Grove and Old Barn it seems to be rather patchy."

The sand which occurs in a pit nearly a mile south-east of Chipping Ongar Station, is described by MR. W. H. PENNING as "nearly white, current-bedded, darker at the bottom, with occasional small patches of dark loamy sand, and a few pebbles and flints, and 15 or 16 feet thick."

PROF. DAWKINS notes a section "northward of Shelley Bridge, showing Boulder Clay, up to 3 feet thick, resting somewhat irregularly on sandy gravel, over 6 feet thick"; and that, "from this place northward towards Moreton there is fine red or grey sand." By the road three eighths of a mile S.W. of Moreton church I saw Boulder Clay, over sand, over clay (? London Clay).

There is a small inlier of gravel along the Roding northward from Fyfield. MR. WOODWARD describes the section at the brickyard here, as follows:—

Boulder Clay, 3 to 4 feet.

Sand, with seams of gravel (chiefly composed of angular flints and quartz), 5 to 6 feet.

Loamy clay (? London Clay).

PROF. DAWKINS has a sketch of a section at Fyfield showing the following beds:—

Brickearth, from 0 to over 8 feet, sloping down over the next, to the bottom.

Boulder Clay, decomposed where at the surface, and where covered by the brickearth also sloping down over the sand beneath, to the bottom.

Sandy gravel, not extending beneath the brickearth.

Fine grey sand, over 6 feet thick.

Between the Roding and the Ingatestone Valley there are several small patches of Glacial gravel, especially bordering the Roding Valley down its left side, which course we will follow firstly.

MR. WOODWARD describes the inlier westward of the Willingales as showing "grey gravel, composed chiefly of pebbles of flint and of quartz, and differing therefore from that of Fyfield, though there is no reason to regard the two as of different ages: they merely show the variable character of the deposit." In a pit more than a quarter of a mile westward of the churches the junction of the Boulder Clay and the gravel was seen.

At Stondon Massey, just south of the church, is a pit, which, according to the notes of PROF. DAWKINS and of MR. BENNETT is from 12 to 20 feet deep in red sandy gravel, weathering white, and composed chiefly of pebbles of flint and of quartz, some of the latter unusually large. There are intercalated beds of sand and the layers are waved, as if by the grounding of ice.

MR. WOODWARD contributes the following:—"There are traces of gravel, but not above some 2 feet thick, beneath the Boulder Clay at Long Spring, northward of Kelvedon Hatch."

"At Navestock Old Park, west of the pond and resting on the London Clay, is a thin trace of pebbly gravel."

"At Chigwell Row, near the Maypole Inn, there is gravelly loam, 6 feet thick, and to the south are irregular patches of gravel, which however are clearly newer than the Boulder Clay. Just south-west of Woodlands loamy gravel, composed of subangular and rolled flints and quartz pebbles has been dug to the depth of 4 feet; but it is not clear whether this is older or newer than the Boulder Clay."

For the description of the small patches away from the Roding MR. WOODWARD's notes are again drawn upon.

"N.E. of Noak Hill there is a pit, by Long Plantation, showing from 6 to 8 feet of rudely bedded gravel and brick-earth, the former composed of angular

and subangular flints, and pebbles of flint and of quartz. At first sight this seems to be older than the Boulder Clay, but gravel may be traced further west over that clay, towards Havering Plain."

"S.E. of Noak Hill, and eastward of the house at Dagnams there is a trace of thin gravel, resting on London Clay."

"North of Home Wood, more than  $1\frac{1}{2}$  miles S.E. of Doddinghurst, there is a thickness of about 3 feet of subangular flint gravel, with pebbles of quartz and of quartzite."

"There are small pits north-westward of Mountnessing Street."

"Between Ingatestone and Frierning there have been large gravel-pits, which were worked down to the London Clay. The gravel is formed chiefly of flint pebbles, derived from the Bagshot Beds, but contains also sandstones and quartzites, besides many broken and a few subangular flints. In a pit, marked on the map, on the northern side of the road between the two places, there was some loam, with pebbles and flints, above the gravel."

"In the railway-cutting at Ingatestone, which is obscure, there is gravel (formed of quartz, angular and rounded flints, and sandstone) sand and loam. The ground between the church and Ingatestone Hall shows a quite unmappable trace of gravel newer than the Boulder Clay, and it seems questionable whether all the gravel between Ingatestone and Margaretting may not be of that age."

"At Margaretting Street about 5 feet of loam was seen on gravel, in ditches, a bed coming in between the Boulder Clay and the gravel, of which last there is but a thin representative here, probably only from 2 to 4 feet thick."

A mile north of Hutton a small cutting, for an approach to the railway (to Billericay &c.) from the western side of the road, showed (in 1887) a scattering of gravelly earth on clay; and just north of the line a little to the east a small pit showed patches of gravel over brown London Clay.

Returning to MR. WOODWARD'S notes, "the patch of gravel south of Hutton is composed chiefly of pebbles of flint and of quartz, with a few angular flints, and has therefore a resemblance to the Pebble Gravel."

Eastward of the Ingatestone Valley there are a few small outliers, MR. WOODWARD'S notes of which it will be convenient to give before taking up the description of the chief mass, along the Chelmer Valley.

"South of Tile Kiln Farm, north of Galleywood, the following section was seen:—

Gravelly soil, from a foot to 2 feet.

Glacial Drift { Boulder Clay, 2 to 6 feet.  
Gravel and sand, seen to about 12 feet.

"Westward of Galleywood the ground, toward the valley, is much covered by loamy gravel; and in a field N.E. of Lodge Farm a small pit has been dug, to the depth of about 4 feet, in pebbly gravel and loam. Quartzite pebbles and worn blocks of pudding-stone occur."

"At Laindon Common, south of Billericay, there is a thin capping of gravel, which increases in thickness toward Great Burstead, and there are some bordering patches. The gravel, dug in several places to a depth of 6 feet, consists of pebbles of quartz and of flint and angular flints, quartzite being rare: it contains loam, and is much concealed by a loamy surface-wash."

"At Dunton Waylet, northward of the village of Dunton, there are two small patches of gravel, the pits in which showed some 6 feet of clayey gravel, composed of subangular flints, flint pebbles and quartz." These have been coloured with the Pebble Gravel however, possibly to avoid using another gravel-colour on the Map (1 S.E.) for so small a tract.

South of the Crouch around Hockley there are some small patches of gravel "which consists of angular flints, flint pebbles, and small quartz pebbles. One mass occurs about a mile S.W. of the church; another is a thin capping on the hill south of the Spa; there is a trace eastward of Plum-burrow Hall; and about three-quarters of a mile westward of Ashingdon is an outlier about two feet thick."

*Essex, Valley of the Chelmer or Blackwater.*

The chief tract of Glacial gravel in the part of Essex with which we are concerned is along the combined valley of the Cann, Chelmer and Blackwater. I fear however that in the large mass between Maldon and Sandon rather too much gravel may have been coloured on the map. It seems likely that London Clay may crop out along the small side-valleys more than has been shown: certainly this is the case at Maldon, where the new railway-cutting enabled me, in 1887, to extend the outcrop of that clay, though perhaps not enough. It is not usual to find gravel draping hill-slopes to such an extent as the map implies, and probably the wash of gravel and sand down the slopes misled Mr. Penning, who surveyed this mass. Gravel generally forms level tracts, either on hill-tops, or at the foot of slopes; though, in the case of River Gravels, it often reaches some way up a slope: to find it spreading from over the top of a hill of fair height and down the slope to the base is most unusual.

Of the tract with which we are now concerned MR. WOODWARD makes the following general remarks:—"Along the valleys of the Chelmer and of the Cann the Glacial gravel is tolerably persistent, and of uniform character, as regards composition and appearance. It may be described as a subangular gravel composed of various sorts of rocks, with seams of sand and patches of loam, sometimes showing current-bedding. The component stones are chiefly flints (subangular, as pebbles, and a few entire), with quartz, quartzites, sandstones, and occasionally trap-rocks."

It will be convenient to describe the sections upward, along the right, or southern, side, and then downward, along the left side, a course which has the advantage of beginning with one of the finest and most interesting sections of Glacial Drift that has been opened in our district, that of the new railway-cutting by Maldon Wick, which proves the occurrence here of a lower bed of Boulder Clay, perhaps representing the lower mass in Suffolk and Norfolk. The following notes of this section were taken in August 1887, before the cutting was finished (northward of the road):—

The northern end of the cutting, near the cemetery, is in London Clay, which was best seen on the western side, where a well-marked layer of septaria showed disturbance of the beds, and perhaps a small fault on the north.

As the ground rises southward the Drift comes on, where a hedge, with trees, crosses the line obliquely, from N.N.E. to S.S.W., about half way between the little stream and the road. Here the eastern side gave the best section, and the following notes therefore refer to it, unless otherwise stated.

The Drift does not come on evenly over the London Clay, but scoops at an angle of 10° or 15°. At first there is some 8 feet of brown sandy clay, with flint pebbles and flints, the bottom foot or more looking like London Clay (from which it was probably made) until examined more closely, when it is seen to be mostly more sandy.

Above this stony loam (which is perhaps only a weathered Boulder Clay) there comes bedded gravel and loam, about 2 feet thick, the stones in which are chiefly flint pebbles: there are also flints, some chalk?, and one large quartzite pebble was seen.

This is succeeded by a mass of brown bedded loam and sand, with some thin gravelly layers, about 10 feet thick.

Then there is a more gravelly and less regular bed (gravelly loam),  $\frac{1}{2}$  9 feet thick, and capped by a clayey soil.

By the spot where the line cuts the next (short) hedge, just south, the gravelly base of this last bed spreads upward, until there is only gravel at top, with grey Boulder Clay beneath; and just south the bottom 3 feet or so of this is sandy and almost stone-less.

London Clay was then seen below, and then, near where the next hedge is cut through, there is an irregular layer of brown clay in the Boulder Clay; and below, or near below, this an irregular gravelly bed, which thickens just to the south, and rests directly on the London Clay.

A little before reaching the road bedded Boulder Clay rises from beneath the top gravel (which rests irregularly on the beds below, being sometimes thick).

The London Clay rises up nearly to the top, sinking again, rising, sinking, and at last rising, for the third time, to the top at the road.

On the other (western) side of the cutting there is a thick mass of gravel.

At the southern mouth of the subway, under the road, the following was the section on the western side:—

Glacial Drift	{	Gravel, about half way down; 12 feet $\frac{1}{2}$
		Mass of clay (London Clay), $\frac{1}{2}$ lenticular; up to 5 feet.
		Gravel; up to 2 $\frac{1}{2}$ feet, with traces of a little Boulder Clay.

London Clay, with an uneven surface; over 2 feet at the least.

On the other (eastern) side the London Clay goes up almost to the top in parts, but is capped irregularly by gravel, over which there is again a mass ( $\frac{1}{2}$  up to more than 8 feet thick) of brown London Clay, probably a continuation of the boulder, as it may be called, on the western side.

Farther south, on the western side there is thick gravel, the London Clay coming up suddenly some way on, beyond which there are irregular patches of gravel. On the eastern side the London Clay reaches higher at first (sometimes to the top) whilst the gravel reaches lower at the last.

Putting together the above facts, which have been recorded as seen in noting the cutting, the succession of beds in the Glacial Drift of this section seems to be as follows:—

Gravel.  $\frac{1}{2}$  at one place becoming a gravelly loam. Overlying, or  
 $\frac{1}{2}$  locally replaced by  
 Brown bedded loam and sand, with gravelly layers, beneath which  
 there occurs, also locally  
 Bedded gravel and loam.  
 Grey boulder clay, or stony loam, with, at the base,  
 Irregular gravelly bed.

"In a pit on Danbury Hill there is now shown a curious contortion, a quantity of London clay being brought up at a sharp angle, and thinned out for some yards between the gravel and sand."\*

MR. H. W. BRISTOW notes that "in a pit on the Common at Horne Row, south of Danbury, there is gravel like that next to be described."

"In a large pit, about ten feet deep, at Sandon the gravel consists chiefly of small flint pebbles, interbedded with thin layers of sand: there are also pebbles of white quartz, a very few of greywether-sandstone, small angular and subangular fragments of flint, and larger flints very little worn."

MR. WOODWARD says that "a little north of the road north of Great Baddow Hall is some laminated very chalky loam, which has been included with the Glacial Drift, though it might well be a later valley-deposit."

MR. BRISTOW again says "the gravel south of Baddow Terrace, N.W. of the village, is largely worked, to a depth of 12 feet. It is pebbly, ferruginous in the upper part, and contains layers of sand, but nevertheless seems to have been very irregularly accumulated. The lower part showed an upward curving of flint pebbles and small fragments of flint in a loose whitish sand, presenting a marked contrast to the more solid accumulation of ferruginous gravel in the

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\* H. CORDER. *Essex Naturalist*, no. 4, p. 92. (1887.)

upper part." Mr. WOODWARD adds that there are occasional layers of clay, and a few boulders of grit in the gravel, above which there is a loamy soil.

Mr. H. CORDER has written as follows on the Drift of this part of Essex:—  
 "There is a peculiarity of the middle glacial gravel beds round Chelmsford . . . . . In most of our sections there are two distinct gravels, the upper third, about, being very coarse and mixed with red clay . . . . . This deposit is almost unstratified. Between this and the underlying beds is very often a thin parting of white clay, sometimes purple, or mixed. Below it are stratified sands and pebble-beds, much paler in colour [than the upper gravel], often white or pale buff. These rest on the London clay, the surface of which, as far as can be seen—for the pits go down to the watery stratum, and do not reach the actual clay—is torn up, and masses are mixed with the lower gravel . . . . . The most beautiful sections are in two large pits on the Baddow road, by the "Beehive" inn, where the two distinct kinds [of gravel] may be well seen, and the colouring is very effective. In one place there is a huge mass of loamy sand, perhaps 30 feet long and 2 feet thick, and which the men say extends a great distance across the field . . . . . It lies somewhat "on the slant," and the gravel beds are contorted at the ends where it sunk through them."\* This probably refers to the section just described.

An apparently hasty statement that teeth of *Elephas primigenius* have been found "in making the railway at Widford" has been corrected, the teeth in question proving to be those of a recent elephant.†

To continue from Mr. WOODWARD's notes, "at Writtle Mill, east of the village, reddish-brown and grey sand and gravel were seen, capped by from 6 to 8 feet of reddish-brown clayey sand with bluish streaks, containing subangular flints and pebbles of flint, quartz etc. This capping may be Post-Glacial. At Rolstons, south-westward of Writtle church, one of the best sections of the gravel with Boulder clay above was seen, the latter resting irregularly on the former, of which a thickness of about 20 feet was shown."

"In the side-valley to the south the merest trace of gravel occurs."

"Gravel-pits were seen near Sturgeons, north-westward of Writtle, and at Hoe Street, S.E. of Roxwell" (see fig. 51). The arrangement of the beds in this district is shown in fig. 50.

"At Roxwell a gravel with boulders of chalk has been dug out of graves in the churchyard."

"Along the valley from Roxwell southward to Cooks Mill the London Clay is exposed at the bottom, and on the eastern side only, except for two slight traces on the other, was the Glacial gravel seen. Boulder Clay caps both sides, and the general section across the valley is as in fig. 49.

Figure 49. Section across the Valley southward of Roxwell.



1. Boulder Clay. 2. Gravel. 3. London Clay.

"At Newland Hall, N.W. of Roxwell there is a small inlier of gravel, which contains pebbles of chalk."

"Gravel was seen in a pit at Blackwall, on the north of the stream, just below Roxwell."

"In the Cann Valley, north of Chignal St. James (just beyond our border, in Sheet 47) a pit showed a Valley brickearth, up to 6 feet thick, cutting down into Glacial gravel."

Mr. F. CHALLIS says that "in the Valley-gravel near Admiral's Park, about 150 yards from the river Cann, several worked flints, including an arrow-head have been discovered;" but Mr. H. CORDER states that the so-called Valley-gravel is "undoubtedly glacial, having its covering of boulder-clay in parts of the section."‡ It is a question whether the worked flints were found in undisturbed Glacial gravel, especially the arrow-head.

\* *Essex Naturalist*, no. 4, p. 92. (1887.)

† *Ibid.*, no. 1, p. 16, no. 11, p. 209.

‡ *Ibid.*, no. 1, p. 16, and no. 4, p. 92. (1887.)

Figure 50. Section from the Valley between Margaretting and Galleghood to the Valley below Roswell. (H. B. WOODWARD.)

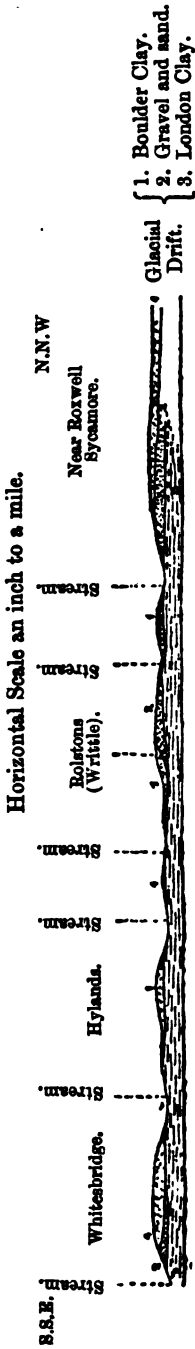
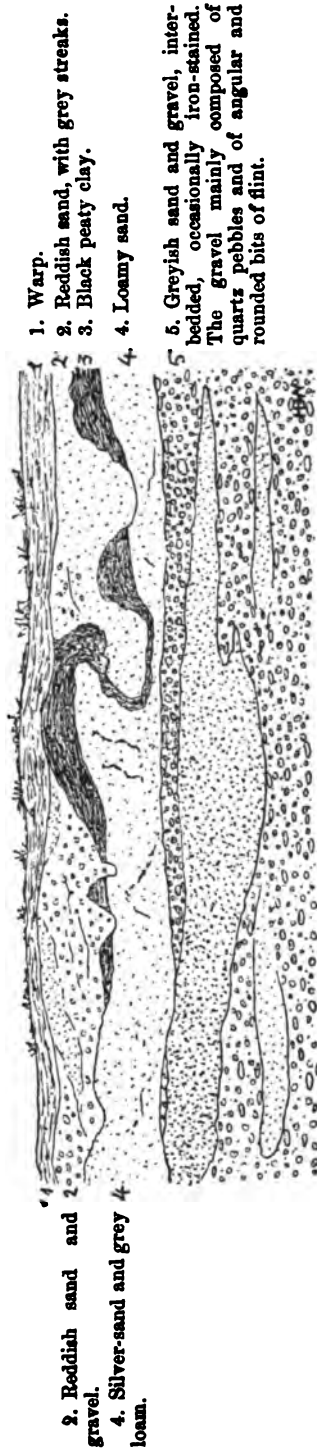


Figure 51. Section at Hoe Street, near Roswell. (H. B. WOODWARD.)

About 12 feet deep.



MR. WOODWARD records that "by the Malting (about  $1\frac{1}{2}$  miles westward of Chelmsford Station), 6 to 7 feet of clayey gravel has been dug, resting on sand, and at Beaumont Oats, up the outcrop to the north, gravel was again seen in a pit."

MR. BRISTOW notes "a large gravel-pit between Bundicks Hill and Rainsford End (the outskirts of Chelmsford) and between the road and the river, where the top covering seems to be resorted material, in which bones have been found, amongst others a human skull. The gravel beneath is brown, made up for the most part of flint pebbles, and with layers of sand; and it was seen to a depth of 12 feet."

MR. WOODWARD says that there are several pits at Broomfield Place, up the Chelmer Valley, and, according to MR. F. CHALLIS "in the Drift-gravel at Broomfield [the village is in Sheet 47] a flint 'scraper' has been found."\*

MR. WOODWARD records a gravel-pit S.E. of Springfield, and MR. W. H. DALTON says that "in the village the gravel under the Boulder Clay has been found to be 22 feet thick," and that "on the high road, between the White Hart Inn, N.E. of the village, and the gates of the avenue leading northward to New Hall Nunnery, some laminated marl occurs, which strongly resembles the shell-marl of the river-terrace at Rivenhall End near Witham."†

MR. WOODWARD notes that "on the west of Boreham there is a trace of Boulder Clay, apparently a bed in the gravel."

MR. DALTON says that "for some way westward of the Blackwater Valley there are only occasional patches of gravel, too thin to be mapped."

Beyond this there are occasional patches of gravel on the London Clay hills, especially to the east, from Goldhanger to Tollesbury, of which part MR. WOODWARD writes as follows:—"In composition this irregular gravel differs from that to the south of the Blackwater, from Bradwell to Burnham, inasmuch as it contains pebbles of quartzite and of Carboniferous (?) sandstone, as well as many large ones of quartz. It is difficult to decide as to the age or manner of formation of this gravel, from the small area over which it occurs and from the absence of Boulder Clay. It may be of Glacial age, while the low-lying gravel, from Langford eastward to Goldhanger, etc. may be a Post-Glacial valley-deposit. The difference of level however is so slight and the composition of the gravels is so similar, that such theoretical notions are of little value."

"At Foleyfaunt, north of Goldhanger, a thickness of two feet of gravel was seen in a pond."

"At Tolleshunt Major [just out of our district, in 48 S.W.] there is rather fine gravel, from 3 to 4 feet thick."

"Southward from that place another mass stretches S.S.E. to beyond Longwick, lying irregularly on the London Clay. Eastward of Holmes, a thickness of 4 feet of gravel was seen, in which good-sized pebbles of quartz were common. North of Downes it has been dug to a depth of 5 feet. Near Longwick it contained pieces of chert that seemed to have been derived from Lower Greensand, as also was the case in the Tolleshunt patch."

"The small patch at Skinnerswick is partly in the side-valley, whilst the high ground just south is bare of gravel."

"At Wick, at the south-eastern end of the Tollesbury mass, 3 feet of gravel was seen." PROF. DAWKINS has noted, at Tollesbury, "4 feet of sandy ferruginous gravel, clayey in the lower part, and with the longer axis of the pebbles lying confusedly."

## BOULDER CLAY.

### *General Account.*

We now come to a deposit of distinctly glacial origin, as shown by its general character, and especially by the scoring on many of the included stones, so like those on stones from existing glaciers.

\* *Essex Naturalist*, no. 1, p. 16. (1887.)

† *The Geology of the N.W. Part of Essex*. (Sheet 47), p. 67. (1878.)

It is essentially a bluish-grey clay, changing mostly to a brown or yellowish-brown by weathering, often more or less sandy, and almost everywhere crowded with stones of various sizes and of many kinds. Large boulders are comparatively rare and a large proportion of the included stones are very small; but there is no dearth of specimens large enough to daunt the strongest and most zealous collector from taking them.

The kinds of rocks represented vary in different places, and have little to do with what formation may next underlie the Drift. This is by reason of the clay and stones having been brought in a general southerly direction, so that the component parts depend on what formations may have been crossed northward. In our district, and over the Eastern Counties, chalk is by far the most common rock, and it is mostly hard, like that which forms a large part of the Yorkshire and of the Lincolnshire Chalk. Flints too are common, whether broken up or in large nodules, and they also occur in the form of pebbles, derived from old Tertiary beds, or from the destruction of gravels of earlier Glacial age.

Besides these home-rocks, as they may be called, there are many fragments of Jurassic formations, chiefly perhaps septarian nodules, from the great clay-masses that must have furnished so much of the material of the containing clay. Oxford Clay and Lias are naturally well represented, being the thickest and most wide-spreading. But we may go far lower than this, Carboniferous sandstone and limestone often occurring, besides older slaty rocks, quartz, quartzites, granites, greenstones, etc. Perhaps among the least frequent of stones, in our district, are septaria from the London Clay.

By the action of carbonated water on the more exposed parts of the Boulder Clay the chalk and other calcareous matter is often dissolved out, and this process, with the oxidation of the colouring-matter of the clay, brings about the formation of an irregular surface-capping of brown, more or less sandy clay or loam, of like character to the Clay-with-flints on the Chalk.

Probably all geologists are agreed that Boulder Clay is a product of ice-action, but when we come to ask in what way this ice-action was brought about there is much discordance. At least three theories have been started and upheld by pertinacious reasoning. The older observers were wont to invoke floating ice-bergs, which dropped their loads in their onward progress southward. Of late years many of our best workers can see signs of nothing but land-ice, and they are somewhat divided, into the advocates of local glaciation (or of extensive glaciers) and of ice-sheets (or wide-spreading continental masses). Others again believe in the action of shore-ice along the slowly-sinking shores of the sea.

Under these circumstances, and as this Memoir is not the place for a controversy of the sort likely to arise from the advocacy of any one theory, it may be well to use that discretion which is the better part of valour, and to pass by the various theories, with



their apparently endless literature, merely asking whether it is absolutely necessary that all Boulder Clay should have been formed in one way? and whether it is not possible that the various agencies suggested may all have been at work at various times and in different places? We have yet much to learn in ice-work.

It is not only as to its origin that the Boulder Clay is a contentious subject, but also as to its relations to other deposits, and, in a much less degree, as to its former range. With the second of these subjects we are hardly concerned now, having freely confessed ignorance whether certain of our local gravels are older or newer than our Boulder Clay. With the range however we are concerned, as our district contains the most southerly masses of the Boulder Clay yet found.

Now these masses all stop short at the northern edge of the Thames Valley, below London. No Boulder Clay has been found down the slopes of the valley, nor in the bottom, nor on the southern side. The same may be said also of the gravel and sand that is clearly associated with (or overlain by) the Boulder Clay, that is to say gravel and sand that can undoubtedly be classed as Glacial Drift. Mostly too the Boulder Clay ends off a little way from the northern edge of the great valley, as at Finchley; on the west, where the hills of Hampstead and of Highgate rise up to the south; and again in Eastern Essex, where Boulder Clay has not been found south of the Crouch.

Is this ending off of the Boulder Clay at the Thames Valley due to denudation simply? or to our having reached, in our district, the southern limit of deposition?

Of course denudation must have had some effect; but the evidence we have, in the utter want of Boulder Clay south of the Thames, would seem to point to the conclusion that the deposit has never reached much farther south than its present limit, and that it must have once ended off against rising ground, either where the valley now is or near by, to the south; a conclusion that implies the cutting out of the Thames Valley in Post-Glacial times, meaning thereby times later than the local Boulder Clay, though very likely not later than other Boulder Clays in more northern parts, with which we have here nothing to do.

It is but right to say that, after this was written, it was found that the above conclusion as to the limit of the Boulder Clay was arrived at years ago by that acute observer of Drift phenomena, MR. J. TRIMMER, who has said "although the boulder clay extends to the northern confines of the valley of the Thames, I have seen no trace of it south of that river," and "it appears to have been cut off by a ridge of eocene tertiaries, of which the Highgate range and Shooter's Hill may be considered the remains. This ridge appears not to have been submerged until the causes which produced the boulder clay had ceased."\*

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\* *Quart. Journ. Geol. Soc.*, vol. vii. p. 25 (1851), and vol. ix. p. 291. (1853.)

The description of sections of Boulder Clay is not a very long matter, there being but small differences, and the more important sections, showing the junction with underlying beds, having for the most part been already described.

### *Hertfordshire.*

Between Watford and St. Albans the Boulder Clay covers the gravel from south of Bricket Wood Common to Burstons Farm, on the north, not crossing the high road on the west, nor going far down into the Valley of the Colne on the east.

A fine section was once to be seen in the railway-cutting, now overgrown, west of Bricket Wood Common. Good sections were seen later in the brick-yard to the west. Information, given by the foreman, of a hole dug to the Chalk enabled MESSRS. WOODWARD and BLAKE to record the following section:—

Glacial Drift	{ Fine clean Boulder Clay; 40 feet.
	{ Gravel and sand; 15 feet.
Chalk.	

"The clay seen was somewhat mottled. Ice-scratched flints, many flint-pebbles, some large unworn flints, boulders of chalk, Carboniferous (?) sand-stones and grits, septaria (probably from the Oxford Clay and from the Lias) and various Jurassic fossils were seen."

MR. WOODWARD adds that "near Waterside Farm, on the east, a pit was seen in chocolate-brown pebbly clay (rather sandy in places and with washes of gravel on the top) and brick-earth."

"The junction of the Boulder Clay and the gravel is not well-marked."

East of St. Albans a mass of Boulder Clay occurs, over loam on the north and west, and over gravel, on the east, from north of Beaumonts Farm to London Colney.

PROF. HUGHES has noted that "in the wood west of Winches Farm there is a great number of pits, said to have been dug for chalk when the road from St. Albans to Hatfield was made, and it is said that in an old chalk-pit, northward of the farm, about 30 feet of stiff clay with stones was found above the Chalk."

The shallow railway-cutting southward of Three Houses is in mottled brown and grey Boulder Clay, with scratched pebbles of hard chalk: gravel and sand peep up from below in parts. The next two cuttings eastward show two or three feet of clay, which in the second is clearly Boulder Clay.

MR. WOODWARD thinks that the Boulder Clay and the brickearth to the west of it are interstratified, as if they were one deposit. He notes "sections of this clay in the road west of Butterwick Farm and south of the wood by Tittenhanger Green."

"East of Nast Hyde is a patch of clay; but no good section was to be seen."

Of the various patches in the south-eastern corner of the county, in the neighbourhood of Bayford, Little Berkhamstead, and Gough's Oak there is nothing noteworthy; enough to say that they mostly rest on Pebble Gravel and on London Clay, crossing from the one to the other, except for those that are on the flank of the Tertiary escarpment, or which, near Hoddesdon and Wormley, partly overlap the Glacial gravel.

### *Middlesex.*

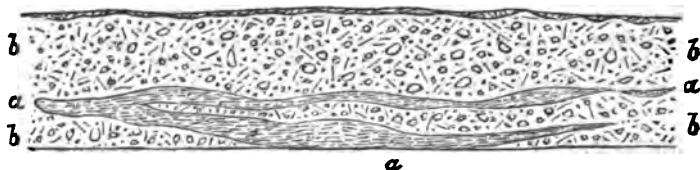
The Finchley mass of Drift has for the most part a capping of Boulder Clay, a continuous sheet, except for the wee outlier on the north.

MESSRS. WOODWARD and GOODCHILD describe a section in Summers Lane, northward of the Islington and St. Pancras Cemeteries, where the clay was being worked for bricks, as follows:—"On the north side of the pit the cutting had lately been newly bared for a length of thirty yards or so, and a

continuous face . . about six feet in height, was exposed. In the middle of the section the upper four feet consisted of the ordinary Boulder Clay of the district; but beneath that, for a length of twenty yards or more, the section showed bands of striped loams, loamy clays, and sands, alternating with, and passing into, Boulder Clay like that above. In another face of the same pit the . . Boulder Clay was seen lying upon the sands and gravels . . . In this case there were signs of gradation."\* Mr. Goodchild has given the drawing for the accompanying figure.

Figure 52. Section in the Brickyard at Summers Lane, Finchley.

(J. G. GOODCHILD.)



Beds of loam and sand (a) interstratified with Boulder Clay (b).

In the excavation for the ornamental water at Mr. H. Stephens' house, the Avenue, southward of Church End Station, a thick mass of Boulder Clay was passed through, to dark brown gravel and sand, seen to a depth of 3 feet or more, when there was water.

The south-eastern end of the cutting S.E. from the station is in Boulder Clay only, which is worked just to the north, in the Manor brickyard.

Along the railway south-eastward there is a short shallow section of Boulder Clay, and the wells at some houses northward of the line passed through this bed and the underlying gravel to the London Clay.

The next railway-cutting, to the S.E., is long, reaching to the East End Station, and is wholly in Boulder Clay, 16 feet deep at the most. The included stones were mostly hard chalk and flints, but with a goodly variety of other rocks and a profusion of specimens of Jurassic species of *Ostrea* and of *Gryphæa*.

The late MR. WETHERELL made a large collection of stones from the Finchley Drift (now, for the most part, in the Museum at Jermyn Street), including an extensive series of British fossils, in a good state of preservation, some of which served the late PROF. J. PHILLIPS in his description of *Belemnites* (*Palæontograph. Soc.*). Amongst the stones is a piece of Red Chalk, the peculiar bed which alone separates the Chalk from the Carstone, or ferruginous sand of the Lower Greensand, at Hunstanton Cliff, in north-western Norfolk, and which has not been found in place any nearer our district than the neighbourhood in question.

The other patches of Boulder Clay in Middlesex, near Southgate and Enfield, are small and of no note.

### Essex.

In this county we have not only a great number of outliers of various sizes; but also the southern ending of the great sheet, which stretches northward across Essex into Cambridgeshire and Suffolk. The border of this sheet runs through our district, in a very irregular course, from near Potter Street, on the north, by Epping Green and Epping Plain, the Lavers, Moreton, Shelley, High Ongar, Blackmore, Highwood, Writtle, Roxwell, Ohignall St. James, and Chelmsford, to Boreham.

\* *Proc. Geol. Assoc.*, vol. x., no. 4, pp. 145, 146. (1888.)

Treating generally of the deposit in this tract MR. WOODWARD says "The Boulder Clay occurs at various levels, often on the highest ground, but sometimes extending some way into the valleys, and sometimes filling hollows; yet generally, in the outlying patches, its boundary keeps nearly to a contour-line. It rests indifferently on the gravels or on the London Clay, and, though rarely found on the Bagshot Beds, must once have covered them."

"Though its boundary can often be traced without much difficulty, yet where this clay rests on the London Clay the task is sometimes difficult: the irregular mode of occurrence, and the clean clay or loam which frequently forms a covering, making the line unsatisfactory. Where there is great doubt it is safer to give preference, as in other like cases, to the older bed, and to regard as London Clay areas in which it is questionable whether or not Drift is present."

"Where the Boulder Clay approaches the Bagshot Beds there is much obscurity, the boundary being generally concealed by a loamy wash, making it difficult to decide whether one is dealing with loams of London Clay or of Bagshot age, or merely with a Post-Glacial capping."

By the kiln on the north of Epping Plain there was a good section.

MR. WOODWARD remarks that "from the gravel of Gayne's Park Wood being covered by a loam, it is very difficult to draw the lines between this gravel, the Boulder Clay and the loamy London Clay. In Ongar Park Wood a pit, N.W. of Parkhouse, showed 8 or 10 feet of the clay, capped by 2 or 3 feet of loam. It is probable that in this neighbourhood the thickness of the Boulder Clay rarely exceeds 12 feet, though northward it may be 20 feet or more."

PROF. DAWKINS says "at Navestock the Boulder Clay is remarkable for the vast quantity of chalk it contains and for the rarity of large boulders. The greatest thickness is 40 feet."

Returning to MR. WOODWARD's notes:—"Traces of sand occur associated with the clay near Albys and Bones Farm, Stapleford Abbots."

"At Pirgo Hall, N.E. of Havering, the soil is loamy and the feature was the only guide in drawing the boundary-line through the park. It is not clear moreover how far southward the clay reaches in the spur to the south-east."

"At Dagnams, near Noak Hill, the boundary is again not satisfactory, being obscured by 3 feet or more of loam S.W. of the house, whilst in other parts there is a gravelly loam, which has been separately mapped where sufficiently important."

"Farther S.E. both loam and Boulder Clay occur at Mayland, and perhaps the clay should have been mapped a little further eastward than it has been."

"The small patch by the cross-roads in the town of Brentwood has been mapped on the authority of the late MR. S. V. WOOD, JUNR., who saw the clay there. In the railway-cutting to the south traces of Boulder Clay occur. The boundary of the patch at Thrift Wood, eastward of the town, is obscure, from the loamy soil, and perhaps it should have been extended."

"The Boulder Clay is very clear and well-marked near Highwood, Writtle and Roxwell, westward of which places good sections were seen at Hoastly Hatch and Windley Green, as also at Blackwall, just east of Roxwell. North of Roxwell there is a loam-capping, which is worked for brick-making, and at Cooksmill Green, southward of the same village, the Boulder Clay, which is well shown and very chalky, contains a little loam at top in places, apparently in pockets."

"One of the best sections was in a pit between Breton Hall and Beaumont Oats, eastward of Chignal St. James, where the following succession was seen :—

Boulder Clay.	{	Brown clay, with a few stones, but free from chalk; about 3 feet.
		Clay, full of chalk; large blocks of flint and of Lias limestone, ice-scratched, the furrows well-marked and in all directions, though the most marked are in the direction of the longer axis of the stones; 10 feet.
		Glacial Sand.

"At the brickyard a mile N.N.W. of Chelmsford church the Boulder Clay is in some places tolerably clean and loamy, though chalky for the most part."

"About Springfield the clay is much obscured by clayey gravel, up to two feet thick. The small irregular patch halfway between this place and Boreham may be a bed belonging to the Gravel series."

"North of Boreham church the clay was well seen in a pit."

"In the small patch near Writtle Mill the following section was seen :—

Grey soil.

Glacial Drift.	{	Reddish-brown sandy clay or loam, with bluish streaks; containing pebbles of flint and quartz and subangular flints;
		6 to 8 feet [decalcified Boulder Clay].
		Reddish-brown and grey sand and fine gravel.

"Good sections were seen in the railway-cutting N.E. of Margaretting Street, at Galley End, just north of Galleywood, and at Great Mascalls, southward of Great Baddow.

"Northward of Stock, Boulder Clay has been mapped at Orsett Hamlet, rather from inference than from direct evidence. It may also cap the high ground to the north, between the house and Galleywood Common; but no sections were seen, and the soil is a rather pebbly loam."

"Good sections were noted by Canon Barns, between South and East Hanningfield, and south of Hill House, north-westward of the last village."

"At Mountnessing the Boulder Clay is obscure, and was best seen in a pit just east of Westlands."

"At Ramsden Mends, S.S.E. of Stock, it is capped by two or three feet of clean mottled brown clay."

"In the tract between Mountnessing, Billericay, and Ingrave, perhaps too little Boulder Clay has been mapped; but in the absence of decided evidence it was thought better not to draw imaginary lines. The boundary of the patch between Hutton and Billericay is very indefinite near Blunt Walls."

The cutting through Arnolds Wood, close to where the railway to Billericay etc. leaves the main line, north-eastward of Shenfield Station, was unfortunately soiled over when I walked along it, in August 1887. At the western part some brown clay was seen at top, some fine brown sand was turned out lower down, and, judging by the dampness, more clay occurred below, the bottom part being then dry. A little further east, before reaching the edge of the wood, a little Boulder Clay was seen, under a little brown clay, the latter being probably a weathered state of the former, as therefore the brown clay previously noted may be also. Touching the line, on the north, at the edge of the wood, is an old pit in Boulder Clay. This cutting must have shown a good junction of Drift and London Clay, which it is to be regretted has escaped observation: whether the sand belongs to the Drift or not one cannot say.

At the railway-cutting two thirds of a mile northward of Ramsden Crays church, a patch of Drift comes on just east of Claypitshills Wood, and was best seen on the northern side, in August 1887. At first (west) the section was :—

A little light-coloured bedded Boulder Clay.

A wedge of brown London Clay, with gravelly loam at the base; apparently a mass lifted up into the Drift.

Brown London Clay, with septaria, grey at the lowest.

Just eastward the London Clay rises up, for a little way, and then the Boulder Clay thickens to 12 feet, but soon ends off, as the ground falls.

On the other (southern) side there is sand, with very little Boulder Clay, and some gravel to the east.

The shallow railway-cutting a third of a mile north-eastward of Purleigh, showed, on the south of the road, a slight hollow of Drift, the beds being as follows :—

Glacial	{	Brown stony clay (P weathered Boulder Clay), a few feet.
Drift.	{	Clayey gravel, a few feet.
Brown London Clay.		

The fields about are stony in parts, and it is hard to say how far the Drift may reach.

## CHAPTER 20. RIVER DRIFT.

## GENERAL REMARKS.

The set of deposits now to be considered have perhaps their most interesting development in our district, along the valley of the Thames, especially below London, where the chief fossiliferous sites and the thickest masses occur.

The sheets, or isolated patches, of gravel and sand and of brick-earth referred to, are confined to the river-valleys, and have clearly been formed by river-action: on that there is now no dispute amongst geologists. As to their age however there has been much discussion, chiefly over the fossiliferous brickearths; though why these should be separated from other and far more widespread masses that happen to be less fossiliferous is a question that the writer, as a field-geologist, cannot understand. All the River Drift should be considered together, whether fossiliferous or not, and the problem of its age and origin cannot be fairly worked out from the investigation of a small part: such separation tends to narrow one's views and leads to the ignoring of the stratigraphical evidence, which after all, in a question of this sort, is by far the most important and the most trustworthy.

As will be seen from what follows the too great importance given to the fossiliferous brickearths of the Thames, below London, has led to those deposits being classed both as Pre-Glacial and as Glacial, whilst the River Drifts as a whole have generally been regarded as Post-Glacial.

None of those three names are here applied to the beds in question, which are classified simply as River Drift, coming after the Glacial Drift, the position which they seem to occupy *in the district*. In other words they are taken to be Post-Glacial as far as the district is concerned, that is to say, as being newer than the Boulder Clay, which is here the top bed of the undoubted Glacial Drift. In various Memoirs I have stated that the term Post-Glacial is therein used in this limited and local sense; but it now becomes a question whether it may not be well to give it up, as likely to mislead, especially in attempts to compare our local Drifts with those of other parts.

Some years ago, when much less was known of the Glacial Drift than now, it was thought that our great southern sheet of Boulder Clay was its top member, not only locally (as is the case in our district), but generally. Further work however has led to the contrary conclusion, for, as we go northward, other beds, of distinctly glacial origin, seem to come on above our southern Boulder Clay; and this is what might be expected: glacial conditions would naturally last longer in northern as well as in higher tracts. From this it follows that the beds which are truly Post-Glacial in a southern district, may be of the same age as others which are clearly Glacial in a northern one.

This being the case, it would seem to be well to avoid the use of such terms as Post-Glacial and Inter-Glacial, except for purely local and subordinate purposes. Our Post-Glacial beds may be equivalent to the Glacial beds of other folk, and Inter-Glacial beds clearly must be part of the Glacial Drift. This last term is a convenient one, and will stand as yet; but Pre-Glacial is probably useless, and moreover has been misleading, so that its loss would not be deplorable. Many geologists have used it for beds of gravel, &c. that underlie Boulder Clay, beds which are generally themselves as much a part of the Glacial Drift as is that clay, and much useless controversy has arisen from this cause. I must own to having used the term myself, though only for a bed (the Pebbly Gravel) which seems to be older than any undoubted Glacial Drift, whilst it is newer than any undoubted Crag, and in this case probably no mischief has been done.

In a description of the Thames Drift, above London, which was published before PROF. PRESTWICH's researches were fully available, the question of the origin of that Drift, then a matter of some debate, was prefaced by the following statement:—"In treating of so difficult a matter, I think it best to confine myself to giving the views of older and more tried geologists. I shall therefore quote various authors who have studied these beds."\*

Somewhat the same course will now be followed: but to a much larger extent as regards the views of authors. If, however, in the Historical Review of the subject, objection is often taken to the opinions quoted, and my own view is sometimes given in a by no means undecided manner, let it not be put down to the absolute loss of former modesty (and modesty should grow with knowledge); but to the fact that one is bound, in the present case, to state one's own opinion, derived from prolonged study of the beds, and to the manifest unfairness of continuing to shelter oneself behind other observers; albeit the shield of PROF. PRESTWICH is used with great advantage.

#### *Character, Composition, and Range.*

The River Drift consists chiefly of gravel, which however often contains beds of sand, and sometimes is almost wholly replaced by sand. Besides this however there is in places a capping of loam, or brickearth, and, in the valley of the Thames below London, thicker masses of a like character sometimes occur alternating with gravel and sand.

The general composition of the Gravel of the Thames has been so well described by PROF. PRESTWICH, that one cannot do better than quote him:

"The great bulk of this gravel is composed of subangular chalk-flints, derived, it may be presumed, from the destruction of portions of the adjacent chalk-surface; whilst, as subordinate materials, we find a considerable number of . . . flint-pebbles,

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\* The Geology of Parts of Middlesex, etc. (Sheet 7). 1864, p. 75.



derived directly, not from the chalk, but from the lower tertiary strata and from the Bagshot sands; also a not inconsiderable number of hard quartzose sandstone-pebbles, pebbles of white quartz, slate, and other rocks . . . and these again derived, not directly from the rocks to which they originally belonged, but, as far as I can judge . . . from the conglomerates of the new red sandstone of Worcestershire and Warwickshire. A singular feature of this gravel is, that although the transport of this debris of the new red sandstone must have passed over the wide band of the oolites of the midland counties, yet but extremely few traces of these rocks are to be found. Of the Lower Greensand and sand of the Portland series a number of the small black pebbles belonging to those beds are met with, but rolled oolitic fragments are very scarce. . . . one considerable block of coral rag was found . . . in a gravel-pit near the Thames between Twyford and Henley. When this gravel reposes on the chalk it is generally mixed at its base with a large proportion of chalk-rubble, which sometimes is concreted and forms a thin solid base or pan to the gravel.”\*

The pebbles of quartzite, etc. probably have not come directly from the New Red Sandstone, but from the destruction of a hill-gravel in Oxfordshire, Berkshire, etc., in which they frequently occur, and from the older gravels of our own district. There is one sort of sandstone however that does not come from either of these sources, namely the Tertiary greywether-sandstone, of which blocks occur somewhat rarely in our River Gravel.

The great rareness of Jurassic limestone in the gravel probably results from such rocks being not only broken up with comparative ease by running water, but also from their being soluble in carbonated water, so that hard masses that survived the torrential action of the river would mostly disappear by the solvent action of infiltrating water, in the upper part of the gravel at all events.

Masses are sometimes hardened into a sort of conglomerate by oxide of iron, and in the chalk-district pieces of chalk often occur throughout the gravel, sometimes in great abundance.

The brick-earth is a brown sandy clay, loam, or clayey sand, very valuable, not only for brick-making, but also for the fine soil that it affords to the market-gardener.

The gravel is rarely more than 20 feet thick. The brick-earth is generally much less, but sometimes more.

MR. W. H. HUDLESTON, in describing the sections at the Law Courts, in the Strand, said of the sands, that “they vary in colour . . . and in size from extremely fine grains to a coarsish grit . . . In the coarser sands the proportion of flint fragments increases, every gradation being passed through till we get to a sandy flint gravel. But whatever their colour, the ordinary sands consists of about 90 per cent. of rounded or sub-angular quartzose grains . . . About 8 per cent. may

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\* *Quart. Journ. Geol. Soc.*, vol. xii. pp. 131, 132. (1856.)

be assigned to dark green bodies, occurring in oval, rounded, and reniform grains; and also, if it be really the same substance, in more or less angular fragments. These may be simply hydrous silicates of iron, or they may be fragments of a more complex pyroxenic mineral . . . ."

"The general colouration of the sands . . . is undoubtedly due to the surface coating or spotting of the quartzose grains with ferric oxide in different states of hydration."\*

DR. H. C. SORBY has said that in the sand associated with flint-gravels, "though sometimes met with in well-rounded grains, flint often occurs as thin flat chips, no doubt on account of its peculiar kind of fracture," and that "in the old deposits of the Thames-valley, like the sand of Hyde Park . . the amount of flint is only 1 per cent."†

MR. J. A. PHILLIPS remarked that "a large proportion of the quartz in the sands of the Thames valley is sharply angular, although mixed with rounded grains of the same size."‡

The above description applies also, more or less, to the Drift of the smaller valleys, in which naturally the tracts are mostly much narrower than in the main valley.

Where valleys have been formed in Chalk they are narrower than where they have been cut through London Clay, and consequently it is in the Tertiary district only that we find broad sheets of River Gravel: thus in the Valley of the Lea there is a wider spread of gravel than in that of the Thames, where the latter river cuts through Chalk alone.

It is therefore where the Thames flows wholly or chiefly through the Tertiary tract, from Taplow to near Purfleet, that the broadest spread of gravel occurs; and in this course there is an exceptionally wide-spreading sheet from Windsor to Brentford, between which places the present river takes a marked southern bend, whilst the northern boundary of the gravel maintains its general easterly trend from Stoke Poges, by Hillingdon, Hayes and Hanwell, to Ealing.

It follows therefore that the gravel occurs to a greater extent on the northern than on the southern side of the river, and below London this is still more marked, there being only small scattered patches on the southern side.

#### *Lie and Position.*

These valley-beds, like the other surface-deposits, of course rest on formations of all ages: in this district from the Chalk to the London Clay. They often mount up the sides of the valleys by a succession of broad steps, or terraces, but sometimes lie evenly on gentle slopes. Each terrace forms a more or less flat tract, often cut through by the main valley, or by side-valleys, deeply enough to lay bare the beds below the gravel.

\* *Proc. Geol. Assoc.*, vol. iii., no. 1, pp. 53, 55. (1873.)

† Presidential Address, *Quart. Journ. Geol. Soc.*, vol. xxxvi., *Proc.*, pp. 56, 65. (1880.)

‡ *Quart. Journ. Geol. Soc.*, vol. xxxvii. p. 19. (1881.)

I found that the mapping of these beds was made the more difficult by the different ways in which they ended off against the older formations. These ways, which are at least three in number, and one of them has many varieties, are shown in Figs. 53 to 56. Of course they pass into one another, so that one cannot always be precise. In Fig. 53 the gravel forms the higher ground, and

*Figs. 53-56. Ending off of the River Gravel.*

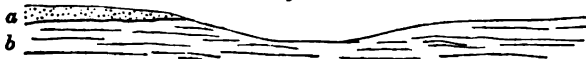
*Fig. 53.*



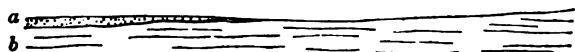
*Fig. 54.*



*Fig. 55.*



*Fig. 56.*



*a Gravel.*

*b Underlying Beds.*

ends off on the downward slope. This form, of course, occurs with high terraces only. I believe that it is nowhere to be found in the western chalk-district, except perhaps at Boyne Hill, W. of Maidenhead; but it may be seen just within the boundary of the Tertiary-country, near Ruscomb, and west of Bray Wick. It occurs on the north of Uxbridge, Hillingdon, and Hayes, at Notting Hill, from Highbury to Stoke Newington, at Wandsworth Common, on the east of Clapham Common, and, of course, wherever a valley cuts through the gravel to the beds beneath. In the high terraces below London it also occurs. In Fig. 54 the gravel is at the base of the hill, and may either end off at the base or creep some way up the slope. This is the general form along the valley of the Thames from Twyford to Maidenhead, the gravel reaching far up the hill-sides from Great Marlow to Well End, Little Marlow. This form likewise occurs from north of Farnham Royal to the Colne, from Windsor to Egham from Hanwell to Wormwood Scrubs, on the south of Richmond, from that place to Wandsworth (excepting where changed by the denudation of the brook near East Sheen, see p. 426), along the boundary of the lower terrace of the Wandle from Tooting to Wandsworth and of the higher at Streatham Common. Again

along the Thames from Brixton to Greenwich, from Erith to Crayford (where the beds run some way up the slope), and on the north, to a great extent, along the border of the broad sheet below the Lea, and more markedly along the narrow terrace of West Thurrock. Fig. 55 is the passage-form between figs. 53 and 54, in which the gravel occurs on one side of a valley and not on the other, or breaks the continuity of a long slope; in the latter case the right-hand slope continues upwards as in fig. 54. This occurs between Wargrave and Twyford, and between Cookham and Maidenhead, where the slight rise of the highest terrace breaks the even slope of the chalk-hills (see fig. 70, p. 391). As this is a passage-form it may be looked for between the places where the first two forms respectively occur. In fig. 56 the gravel gradually thins off in a flat, and this is naturally the most difficult boundary to find out, as it makes no feature at the surface. It occurs in the valley of the Loddon, S. and N.E. of Hurst; and in the Thames Valley from the south of Bray to Windsor, at the southern end of Regent's Park, and thence a short way eastward; but nowhere in the chalk-district, owing to the comparative hardness of the Chalk.

It must not be thought that the present boundary of the valley-beds is always their original one, and shows the whole extent of surface over which they have spread. The fact of their being often worn through by side-valleys, along the lower part of which the underlying beds are thereby laid bare, has been already noticed; but besides this there has been another and greater denudation, for it is clear that where the gravel now ends off, as in fig. 53, it must once have spread further: one cannot imagine a deposit from water confined within more or less narrow limits, by the rising ground on either side of a valley, to end off in this way; it must clearly have spread to the base of the bounding hills, and the present form must therefore be owing to denudation.

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The general character and position of the River Drift having been noticed, its origin can best be discussed in noticing and reviewing the various books and papers that have treated of the subject.

#### *Fossils.*

The River Drifts of our district have an interest beyond that of the older gravels etc., because of their containing fossils, though these are by no means always found, being comparatively rare, except in certain tracts. From these fossils we can learn much as to the life of the period, a knowledge that is wanting as regards the other beds alluded to, and the want of which greatly helps to divert observers from studying them: few things are less interest-

ing to young geologists than unfossiliferous beds; whilst to the palæontologist and to the fossil-collector they are a waste of space! The mere fact that bones and shells are found in the gravel and brickearth of the valleys has incited a great number of collectors to investigate them and to note sections in them.

The fossils of these beds belong almost wholly to two great groups, the Mollusca and the Mammalia. The *Mollusca* consist chiefly of fluviatile and terrestrial univalves, of which all the species but one, *Hydrobia marginata*, are now living in our country: there are also fluviatile bivalves, of which two species, *Corbicula fluminalis* and *Unio littoralis*, do not now occur in England. The three species above-named however all live elsewhere; there is not a single extinct species. With the *Mammalia*, on the other hand, it is different: we have firstly a number of species (twelve, not including man) still living in our islands, or which have been with us in historic times; then a number (ten) that have long since ceased to live with us, though existing elsewhere; and lastly a number (seven) that are wholly extinct. The co-existence of these extinct, and mostly large, mammals with man, whose presence is abundantly proved by his works, is of great interest, and points to conditions very different from those that now hold; but into the questions of the climate of the period and of the probable migrations of the *Mammalia* one cannot now enter: they have been very fully discussed by authors whose works will be duly noticed, and to which the reader is referred as regards those questions.

Whilst the fossils of the River Drifts unmistakeably prove their origin from fresh water, they have given rise to much dispute as to their age, relatively to other Pleistocene beds and amongst various parts of themselves. Of course as the shells are all of recent, and very nearly all of British species, it is needful at once to put them aside as valueless, if one wants to make out these beds to be of creditable antiquity. By this means one has to fall back on the *Mammalia* alone, and then, paying special attention to the extinct species, and emphasizing those which can be shown to have originated in earlier times, it comes to this, that there is one animal alone, of the extinct forms dating from an earlier period, the big-nosed rhinoceros, whose remains have been found in no other part of our River Drift than the local brickearths of Essex and of Kent, which to me seems to go very little way indeed toward showing that those brickearths are older than other parts of the River Drift. It seems to me that it would be better frankly to confess that the fossils throw very little light on the subject, and are of very small classificatory value, though in themselves of high interest.

It is curious to note how purely palæontological reasoning has led to error in assigning to our River Drift its place in the geologic series. Naturally this reasoning has referred chiefly to the great fossiliferous locality of Grays, the beds at which have been treated almost as an independent set, apart from those that occur in other parts of the valley.

It is strange that whilst geologists are generally ready to give their full value to palæontological reasons, yet palæontologists sometimes show a tendency to dogmatise on geological matters, and to pass over stratigraphical considerations, or those which depend on the character and position of the beds, as things of small importance, though the field-geologist may have worked long and hard at them. The two lines of evidence should be combined, though perhaps only stratigraphical evidence can decisively settle questions of the relative age of nearly related deposits.

The following list has been compiled from the most trustworthy local and general lists, as shown below, the names having been carefully revised by MR. G. SHARMAN and MR. E. T. NEWTON, the latter of whom indeed got together nearly all the material for the Vertebrata. MR. B. B. WOODWARD also gave his aid, in the revision of the Mollusca.

The localities are shown by figures, as below. It was thought to be needless to differentiate the various localities grouped under 5, though somewhat far apart; whilst those under 6 are all near together. Moreover in these cases the sections that have yielded the fossils are mostly small and very temporary.

1. *Ilford*. PROF. W. B. DAWKINS, *Quart. Journ. Geol. Soc.*, vol. xxiii., pp. 100, 101 (1867), vol. xxv., pp. 196-199 (1869), and vol. xxxvi., p. 398 (1880); A. TYLOR, *Ibid.*, vol. xxv., pp. 99, 100 (1869).
2. *Grays*. S. V. WOOD, Monograph of the Crag Mollusca, vol. ii., no. 3, pp. 306-308, *Palæontograph. Soc.* 1856; PROF. W. B. DAWKINS and, A. TYLOR, (as under *Ilford*); R. LYDEKKER, Cat. Foss. Mamm. Brit. Mus. (1885 &c.)
3. *Erith*. PROF. W. B. DAWKINS and A. TYLOR, as above, R. W. CHEADLE and B. B. WOODWARD, *Proc. W. Lond. Sci. Assoc.*, vol. i., pt. iii., pp. 97, 98 (1876); and R. LYDEKKER, Cat. Foss. Mamm. Brit. Mus. (1885 &c.)
4. *Crayford*. PROF. W. B. DAWKINS, A. TYLOR, R. W. CHEADLE, and B. B. WOODWARD, as above.
5. *West of London*. Ealing, J. A. BROWN, "Palæolithic Man in N.W. Middlesex," p. 113 (1887). Brentford, PROF. MORRIS, *Quart. Journ. Geol. Soc.*, vol. vi., p. 203 (1850), PROF. DAWKINS, *Ibid.*, vol. xxv., pp. 196-199 (as also Hurley and Kew).
6. *North London*. Clapton, WORTHINGTON SMITH, *Trans. Essex Field Club*, vol. iii., pt. 7, p. 119 (1883) and *Nature*, 1882, p. 581; Hackney (and Shacklewell), PICKERING, in Prof. Prestwich's paper, *Quart. Journ. Geol. Soc.*, vol. xi., p. 110 (1855), and WORTHINGTON SMITH, *Geol. Repertory*, vol. i., p. 373 (1867); Highbury, A. TYLOR, *Geol. Mag.*, vol. v., p. 391 (1868); Stoke Newington, J. W. MASON, in Mr. A. Tylor's paper, *Quart. Journ. Geol. Soc.*, vol. xxv., p. 99 (1869), J. E. GREENHILL, Prehistoric Hackney, Paper ii., 1883. Mammalia partly from PROF. DAWKINS, *Quart. Journ. Geol. Soc.*, vol. xxv., pp. 196, 197.

Peckham has also yielded 7 species, East Wickham 5, and Dartford 2; but they are all included in the following list.

## MAMMALIA.

## Primates.

*Homo*. (Man, by his implements). Very many places. See *Flint Implements*, p. 338.

*Macacus pliocenus*, *Owen* - - - - - 2

## Carnivora.

<i>Canis lupus</i> , <i>Linn.</i>	-	-	-	-	-	1	2	3	4	5	6
„ <i>vulpes</i> , <i>Linn.</i>	-	-	-	-	-	1	2	—	—	—	6
<i>Felis catus</i> , <i>Linn.</i>	-	-	-	-	-	—	2	—	—	—	—
„ <i>leo</i> , <i>Linn.</i>	-	-	-	-	-	1	2	3	4	5	6
<i>Hyæna crocuta</i> , <i>Erzl.</i> var. <i>spelæa</i>	-	-	-	-	-	—	2	—	4	5	—
<i>Lutra vulgaris</i> , <i>Erzl.</i>	-	-	-	-	-	—	2	—	—	—	—
<i>Ursus arctos</i> , <i>Linn.</i>	-	-	-	-	-	1	2	—	4	—	6
„ <i>horribilis</i> , <i>Ord.</i> (= <i>ferox</i> , <i>Richd.</i> )	-	-	-	-	-	1	2	—	4	—	6

## Ungulata.

<i>Bison bonasus</i> , <i>Linn.</i> var. <i>priscus</i> , <i>Boj.</i>	-	-	-	-	-	1	2	—	4	5	6
<i>Bos taurus</i> , <i>Linn.</i> var. <i>primigenius</i> , <i>Boj.</i>	-	-	-	-	-	1	2	3	4	—	6
<i>Cervus elaphus</i> , <i>Linn.</i>	-	-	-	-	-	1	2	3	4	5	6
„ <i>giganteus</i> , <i>Blum.</i> (= <i>Megaceros hibernicus</i> )	-	-	-	-	-	1	2	3	4	5	6
„ ( <i>Capreolus</i> ) <i>capra</i> , <i>Gray.</i>	-	-	-	-	-	1	2	—	—	5	6
„ ( <i>Rangifer</i> ) <i>tarandus</i> , <i>Linn.</i>	-	-	-	-	-	—	—	—	—	5	6
<i>Elephas antiquus</i> , <i>Falc.</i>	-	-	-	-	-	1	2	3	4	5	6
„ <i>primigenius</i> , <i>Blum.</i>	-	-	-	-	-	1	2	3	4	5	6
<i>Equus caballus</i> , <i>Linn.</i> (= <i>fossilis</i> , <i>Meyer</i> )	-	-	-	-	-	1	2	3	4	5	6
<i>Hippopotamus amphibius</i> , <i>Linn.</i> (= <i>major</i> , <i>Owen</i> )	-	-	-	-	-	1	2	—	—	5	6
<i>Ovibos moschatus</i> , <i>Zimm.</i>	-	-	-	-	-	—	—	—	4	5	—
<i>Rhinoceros antiquitatis</i> , <i>Blum.</i> (= <i>tichorhinus</i> , <i>Fischer</i> )	-	-	-	-	-	1	—	3	4	—	6
„ <i>leptorhinus</i> , <i>Owen</i>	-	-	-	-	-	1	2	3	4	5	6
„ <i>megarhinus</i> , <i>Christol</i>	-	-	-	-	-	1	2	—	4	—	6
<i>Sus scrofa</i> , <i>Linn.</i>	-	-	-	-	-	—	2	—	—	5	6

## Rodentia.

<i>Arvicola amphibius</i> , <i>Linn.</i>	-	-	-	-	-	1	2	—	4	—	6
„ <i>ratticeps</i> , <i>Keyserling</i> and <i>Blasius.</i>	-	-	-	-	-	—	—	—	4	—	—
<i>Castor fiber</i> , <i>Linn.</i> (= <i>europæus</i> , <i>Owen</i> )	-	-	-	-	-	1	2	—	—	—	6
<i>Spermophilus erythrogenoides</i> , <i>Falc.</i>	-	-	-	-	-	—	—	—	3	—	—
„ <i>sp.</i>	-	-	-	-	-	—	—	—	3	4	—

## Insectivora.

<i>Sorex</i> - - - - -	-	-	-	-	-	—	2	—	—	—	—
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## AVES.

<i>Anas</i> (In the Jermyn Street Museum) -	-	-	-	-	-	1	—	—	—	—	—
<i>Anser</i> ( „ „ „ ) -	-	-	-	-	-	1	—	—	—	—	—

## FISHES.

<i>Esox lucius</i> , <i>Linn.</i> (W. DAVIES. "Catalogue of the Collection of Sir Antonio Brady, 1874") -	1	—	—	—	—	—	—	—	—	—	—
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## MOLLUSCA.

## Gasteropoda.

<i>Ancylus fluviatilis</i> , Müll.	-	-	-	1	2	3	4	—	6
„ [Velleitia] lacustris, Linn.	-	-	-	—	2	—	—	—	6
<i>Balea perversa</i> , Linn. (= <i>fragilis</i> , Drap.)	-	-	—	—	2	—	—	—	—
<i>Bythinia tentaculata</i> , Linn.	-	-	-	1	2	3	4	5	6
<i>Cæcilianella</i> [ <i>Achatina</i> ] <i>acicula</i> , Müll.	-	-	—	—	2	—	—	—	6
<i>Carychium minimum</i> , Müll.	-	-	-	1	2	3	4	—	6
<i>Clausilia biplicata</i> , Mont.	-	-	-	—	2	—	—	—	6
<i>Cochlicopa</i> [ <i>Zua</i> ] <i>lubrica</i> , Müll.	-	-	-	1	2	—	—	—	6
<i>Helix aculeata</i> , Müll.	-	-	-	—	—	—	—	—	6
„ <i>arbusorum</i> , Linn.	-	-	-	—	—	2	—	—	6
„ <i>caperata</i> , Mont. (= <i>fasciolata</i> , Poir.)	-	-	—	—	—	3	4	—	—
„ <i>fulva</i> , Müll.	-	-	-	1	—	—	—	—	—
„ <i>hispidula</i> , Linn.	-	-	-	1	2	3	4	—	6
„ „ var. <i>concinna</i> , Jeffr.	-	-	-	—	—	2	3	4	—
„ <i>nemorialis</i> , Linn.	-	-	-	1	2	3	4	—	6
„ <i>pulchella</i> , Müll.	-	-	-	—	—	2	3	4	—
„ <i>pygmæa</i> , Drap.	-	-	-	—	—	2	—	—	—
„ <i>rotundata</i> , Müll.	-	-	-	—	—	2	—	—	5
„ <i>rudrata</i> , Studer	-	-	-	—	—	2	—	—	—
„ <i>rufescens</i> , Pen.	-	-	-	—	—	2	—	—	6
<i>Hyalinia</i> [ <i>Zonites</i> ] <i>crystallina</i> , Müll.	-	-	-	—	—	—	4	—	6
„ „ <i>nitidula</i> , Drap.	-	-	-	—	—	2	—	4	—
„ „ <i>radiatula</i> , Alder	-	-	-	—	—	2	4	—	6
<i>Hydrobia</i> [ <i>Paludina</i> ] <i>marginata</i> , Mich.	-	-	-	—	—	2	3	4	5
<i>Limax agrestis</i> , Linn.	-	-	-	—	—	2	—	—	—
„ <i>marginatus</i> , Müll. (= <i>Sowerbyi</i> , Fer.)	-	-	-	—	—	2	—	—	—
<i>Limnæa auricularia</i> , Linn.	-	-	-	1	2	3	4	5	6
? „ <i>glabra</i> , Müll.	-	-	-	—	—	—	—	—	6
„ <i>palustris</i> , Müll.	-	-	-	1	2	3	4	—	6
„ <i>peregra</i> , Müll.	-	-	-	1	2	3	4	5	6
„ „ var. <i>ovata</i> , Drap.	-	-	-	—	—	—	3	4	—
„ <i>stagnalis</i> , Linn.	-	-	-	1	2	3	4	5	6
„ <i>truncatula</i> , Müll.	-	-	-	1	2	3	4	—	6
<i>Paludina contracta</i> , Millet (= <i>Listeri</i> , Forbes)	-	-	-	—	—	—	4	—	—
<i>Planorbis albus</i> , Müll.	-	-	-	—	—	2	3	4	—
„ <i>carinatus</i> , Müll.	-	-	-	1	2	3	4	—	6
„ <i>complanatus</i> , Linn. (= <i>marginatus</i> , Drap.)	-	-	-	—	—	2	3	4	—
„ <i>contortus</i> , Linn.	-	-	-	—	—	2	—	—	6
„ <i>corneus</i> , Linn.	-	-	-	1	2	3	4	—	—
„ <i>glaber</i> , Jeffr.	-	-	-	—	—	2	—	—	6
„ <i>nautilus</i> , Linn.	-	-	-	—	—	2	—	—	6
„ <i>nitidus</i> , Müll.	-	-	-	—	—	2	—	—	6
„ <i>spirorbis</i> , Linn. (= <i>rotundatus</i> )	-	-	-	—	—	2	3	4	—
<i>Pupa marginata</i> , Drap. (= <i>muscorum</i> , Linn.)	-	-	-	1	2	3	4	—	6
„ <i>umbilicata</i> , Drap.	-	-	-	—	—	—	—	—	6
<i>Rissoa</i> , sp. (in Mus. Jermyn Street)	-	-	-	—	—	2	—	—	—
<i>Succinea elegans</i> , Risso	-	-	-	—	—	—	3	—	—
„ <i>oblonga</i> , Drap.	-	-	-	—	—	—	3	—	—
„ <i>putris</i> , Linn.	-	-	-	1	2	—	4	5	—
<i>Valvata cristata</i> , Müll.	-	-	-	—	—	2	3	4	—
„ <i>piscinalis</i> , Müll.	-	-	-	1	2	3	4	5	6
„ „ var. <i>antiqua</i> , Mor.	-	-	-	—	—	2	—	—	—
<i>Vertigo</i> [ <i>Pupa</i> ] <i>antivertigo</i> , Drap.	-	-	-	1	2	—	—	—	—
„ „ <i>pusilla</i> , Müll.	-	-	-	—	—	2	—	—	—

## Lamellibranchiata.

<i>Anodonta cygnea</i> , Linn.	-	-	-	1	2	3	4	5?	—
<i>Corbicula fluminalis</i> , Müll. (= <i>Cyrena consobrina</i> )	-	-	-	1	2	3	4	—	6
<i>Pisidium amnicum</i> , Müll.	-	-	-	1	2	3	4	5	6



<i>Pisidium fontinale</i> , <i>Drap.</i>	-	-	-	-	1	2	3	4	—	6
„ „ var. <i>henslowianum</i> , <i>Shepp.</i>	-	-	-	-	—	—	—	4	—	6
„ „ „ <i>pulchellum</i> , <i>Jenyns</i>	-	-	-	-	—	—	—	—	—	6
„ „ <i>pusillum</i> , <i>Gmel.</i>	-	-	-	-	—	2	—	—	—	6
„ „ var. <i>obtusale</i> , <i>Pfeiff.</i>	-	-	-	-	—	—	—	4	—	6
<i>Sphærium</i> [ <i>Cyclas</i> ] <i>corneum</i> , <i>Linn.</i>	-	-	-	-	1	2	3	4	5	6
<i>Unio littoralis</i> , <i>Lam.</i>	-	-	-	-	1	2	3	4	5	—
„ <i>pictorum</i> , <i>Linn.</i>	-	-	-	-	1	2	—	4	—	6
„ <i>tumidus</i> , <i>Philippson</i>	-	-	-	-	1	2	—	—	—	6

## PLANTÆ.

? <i>Pinus sylvestris</i> , <i>Linn.</i>	-	-	-	-	—	—	—	—	—	5
Fern-rhizome (? <i>Lastrea filix mas</i> , or <i>Osmunda regalis</i> )	-	-	-	-	—	—	—	—	—	5

These two from Acton, GEN. PITT-RIVERS' Paper, *Quart. Journ. Geol. Soc.*, vol. xxviii. p. 455.

In addition to these *Valvata piscinalis*, var. *depressa*, Pfeiff. has been recorded from Erith by M. G. DOLLFUS; but English palæontologists do not accept the identification.

It may be in keeping to note a remark made by MR. WORTHINGTON SMITH, which is of a consolatory nature to observers. He refers to PROF. PRESTWICH's paper on the gravel of West Hackney (1854), and to the fact that, at the time the observations on which it is based were made, flint implements escaped notice, though since they have proved to be of common occurrence thereabout; and he says "it is also remarkable that although a list of shells is given in that paper, yet it does not include the only two of special interest," *Corbicula fluminalis* and *Hydrobia marginata*, now extinct in England, the moral drawn being that "one may be sometimes very near a curious discovery and yet miss,"\* to which one may add the lesson that even when a great master of the science has carefully described a section there may yet be important points left for other and humble workers to note, from fresh evidence. I would point to the gaps in our list, and would suggest the advisability and the probability of some of them being filled.

PROF. PRESTWICH however writes to me that the pit he described was not amongst those seen by Mr. Smith, as it had been built over. He has also found a note of his last visit to Shacklewell, in 1859 (when another part of the pit was being worked) in which the following words occur:—"Found one *Cyrena consobrina* in the grey clay under the gravel."

*Flint Implements.*

It has been already remarked how the occurrence of fossils has given some zest to the study of the River Drifts. Still more interesting however did they become when it was known that flints, fashioned by the hand of man into tools or weapons, had been found in them, and that they bore witness to the antiquity of man, and to his co-existence in our country with great extinct pachyderms and other mammals.

At first of course the artificial character of the flint implements was questioned; but into that question it is needless to enter, as no one who knows anything about the subject and comes to it with an unbiassed mind has now any doubt. Then their occurrence in place in the gravels was questioned, and it was suggested that they were later introductions, that the gravel had been resorted, etc.; neither is there any need to discuss this, as many

\* *Nature*, vol. xxvii. pp. 270, 271. (1883.) A paper further quoted in the sequel.

undoubted implements have been found, by trustworthy observers, in beds that have not been disturbed since deposition.

No complaint is made of these doubts; they have served only to sharpen observers, to make them careful, and in the end to establish the case. It would be strange indeed were any such discovery to be at once accepted to the uttermost, and probably it would also be unwise. There is nothing like a little wholesome scepticism and fair opposition in such a case, in order to get rid of doubtful points, and to see that the zeal for a new theory is not allowed to overrun discretion, as it often does. Luckily this subject was originally taken up by the best observers.

Attention was first drawn to the occurrence of worked flints in gravel in France, in 1847, by M. BOUCHER DE PERTHES; but it was not for more than ten years that his conclusion was accepted. This discovery, made so early as 1841, met with little notice, and perhaps no acceptance, until 1854 (later in France), and it was not finally believed until some years after, when DR. FALCONER drew PROF. PRESTWICH'S attention to the facts which he thought M. BOUCHER DE PERTHES had established, in the neighbourhood of Amiens. This led to the matter being taken up by PROF. PRESTWICH and DR. J. EVANS, who worked out the question in detail, convinced English geologists that flints worked by man occurred in undisturbed River Drifts, and transferred the investigation to their own country. The above observers were soon joined by SIR C. LYELL and by others, and the great mass of English geologists was at once converted to the new faith. In the words of DR. EVANS "From the day when Mr. Prestwich gave an account to the Royal Society of the results of his visit to the Valley of the Somme, the authenticity of the discoveries of M. Boucher de Perthes and Dr. Rigollot [1855] was established; and they were almost immediately followed by numerous others of the same character, both in France and England. In this country, indeed, it turned out, on examination, that more than one such discovery had been recorded, and that flint implements . . . had been found in the gravels of London at the close of the seventeenth century, and in the brick-earth of Hoxne, in Suffolk, at the close of the eighteenth, and were still preserved in the British Museum, and in that of the Society of Antiquaries."\*

The first two records of implements in the Drift therefore were made in England, and, again to quote DR. EVANS "the Thames Valley may . . . lay claim to the first recorded discovery of any flint implement in the Quaternary gravels." This is a very fine specimen, and "it would seem to have been found, with a skeleton of an elephant, in the presence of Mr. Conyers" near Gray's Inn Lane. For the illustration of this implement (fig. 57), and for the three following figures we are indebted to the liberality of DR. EVANS, whose beautifully illustrated work should be in the hands of all workers on this subject.

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\* "The Ancient Stone Implements . . . of Great Britain," p. 478. (1872.)

*Fig. 57. Flint Implement from London in the British Museum.*



"No. 246. A British weapon found, with elephant's tooth, opposite to black Mary's, near Grayes Inn Lane. Conyers. K." (Sloane Catalogue). K = Kemp's Collection. Fig. 451, p. 522, of Dr. Evans' book. Actual size.

The next recorded find noticed by Dr. Evans was that by MR. G. H. GAVILLER of an implement, shown by fig. 58, from gravel at Hackney Down. This was followed by DR. EVANS' youngest son, MR. NORMAN EVANS finding that illustrated by fig. 59 in a brickyard at Highbury New Park, in 1868, though not in place.

The next year however a fairly wholesale discovery was made in the neighbourhood of Acton and Ealing by COL. LANE-FOX, now GEN. PITT-RIVERS (certainly a fit name for a finder of implements in pits in River Drift), and was recorded in the following year.\* It will be better however to refer to the fuller account, which appeared in 1872.† No success attended the endeavours to find implements in the brick-earth of the mid-terrace; but the repeated watching of excavations for the foundation of houses, for sewers, etc. was rewarded by the discovery of 22 implements and 160 flakes in the high terrace gravel. The author says "I found that in every instance [at Acton] the implements came out of the lowest stratum of the gravel." Mammalian remains occurred in that of the mid-terrace, in which no implements were found.

On the south of the Thames this observer found one implement and one flake, at Battersea Rise. Of the flakes DR. EVANS says that they "are for the most part large and rude . . . . Two have been wrought into the scraper form. Some cores or blocks of flint from which flakes have been struck have also been found." Of some flakes said to have been found under 9 feet of Drift, north of Chaucer Road, GEN. PITT-RIVERS said "the position of these flakes is of interest, on account of the edges . . . being as sharp as when they were flaked off from their cores, proving that, whilst the majority of the flakes and implements . . . were carried down by the water and rolled in the gravel, . . . these, on the contrary, must have been flaked off on the spot, after which the deposits of gravel and brick-earth must have accumulated over them."

Another record that DR. EVANS gives us is of the implement shown in figure 60, which was found by MR. F. C. J. SPURRELL "in situ, lying on its side, at a depth of 8 feet below the surface of the gravel, which is that of the upper level of Dartford Heath."

In the same year the REV. O. FISHER found a flake in the Slade's Green Pit, Erith, "out of a band of rounded flint gravel lying beneath the sandy stratum which contains abundance of shells . . . together with mammalian remains," the bed in question being 11 feet down. The author continues "As far as I know, this is the first instance of obtaining evidence of the existence of man in this country in association with *Corbicula* (or *Cyrena*) *fluminalis* . . . And I think this is the first time of finding anywhere a chipped flint in association with *Unio litoralis*."‡

Four years later MR. R. W. CHEADLE "was also fortunate enough to find another [flake], which he took out of the undisturbed earth about two inches above the shell band at Erith."§

\* *Rep. Brit. Assoc.* 1869, *Sections*, pp. 130-132. (1870.)

† *Quart. Journ. Geol. Soc.*, vol. xxxiii. p. 449.

‡ *Geol. Mag.*, vol. ix., p. 263. (1872.)

§ *Proc. W. Lond. Sci. Assoc.*, vol. i., pt. iii. p. 97., figured p. 96. (1876.)

Fig. 60. Flint Implement from Dartford Heath. Half actual size. (Fig. 456 of Dr. Evans' Book.)

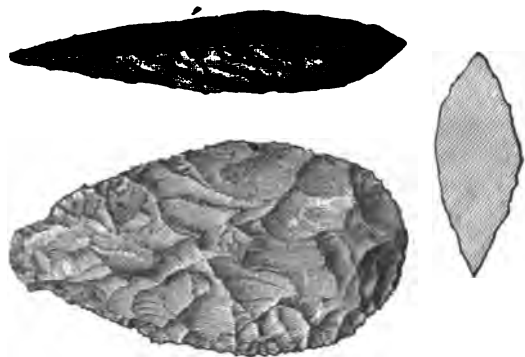


Fig. 59. Flint Implement from Highbury New Park. Half actual size. (Fig. 453 of Dr. Evans' Book.)

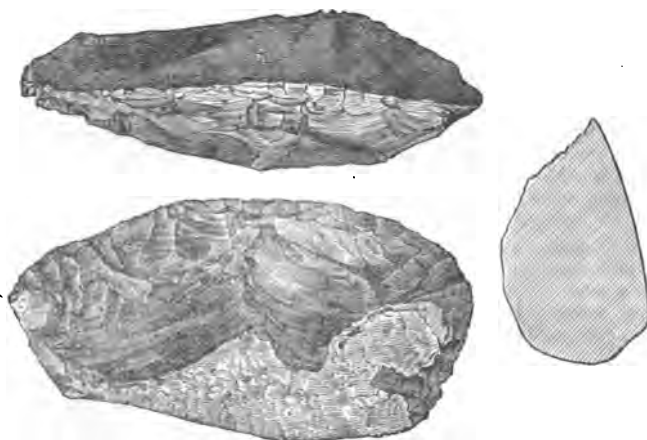
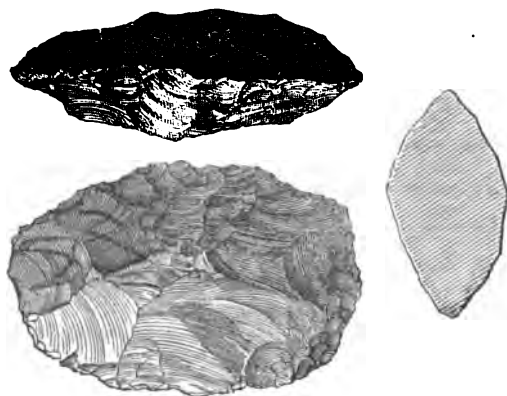


Fig. 58. Flint Implement from Hackney Downs. Half actual size. (Fig. 452 of Dr. Evans' Book.)



But since the publication of DR. EVANS' book, and of GEN. PITT-RIVERS' paper, the work of finding, and of recording, flint implements in large numbers along the lower part of the Thames Valley has been taken in hand by a band of skilled local observers. The researches, taking them in the order in which their first record has appeared, of MR. WORTHINGTON SMITH, of MR. SPURRELL, of MR. J. E. GREENHILL, and of MR. J. A. BROWN have shown how rich our River Drift is in implements, and that a trained eye and a patient examination of sections will be duly rewarded.

In 1879 MR. SMITH began his set of papers, by a note "on Palæolithic Implements from the Valley of the Lea,"\* and at the outset one must notice a slight topographical error into which this author has fallen, on various occasions; but which he has frankly acknowledged, in a letter to me: he often speaks of the Valley of the Lea when the sites referred to are really in the main valley, that of the Thames, near where its gravel is cut through by the tributary valley of the Lea: the gravel of Hackney, Highbury, etc. is old Thames gravel.

MR. SMITH first refers to Shacklewell, where the pits are "near the north-east corner of West Hackney Church . . . the gravel and sand vary greatly in thickness and disposition . . . Freshwater shells are generally abundant . . . Bones of mammalia also occur," and, he says "I found several flint flakes of Palæolithic age *in situ*" and an implement on a heap of gravel. At Upper Clapton he "found a considerable number of flakes and one . . . implement." Lower Clapton "has produced more implements, flakes and cores than Upper Clapton or Shacklewell," probably most of them "from a thin deep-red seam of gravel, which is commonly about 10 feet beneath the surface" and in which he found implements in place.

He then notes the following localities, in the Valley of the Lea, Tottenham Cross, Lower Edmonton, Waltham Station, and Flamstead End (Cheshunt) as yielding flakes, etc.

In 1880 MR. SPURRELL, who had seen flint flakes in the pits at Crayford, but was doubtful as to what bed they came from, at last "on the removal of a part of the face of the cliff . . . came upon a dense layer of chips." At one spot, by the old chalk-cliff, against which the brickearth abuts, "a sort of foreshore seems to have been formed, consisting here of hard sand, and there of small heaps of flint stones brought down from the cliff by aerial action. It is in one of these small slopes of sand that the layer of flakes was found. The uppermost edge of the area covered by them is about thirty-six feet from the present surface, the lowest nearly six feet lower. This area was thickly covered with chips for the space of about ten feet north and south, and, as far as I know at present, fifteen feet east and west . . . but I expect that it will be found to extend further."

"The fragments of flint lay touching each other, in parts to a thickness of several inches, and had fallen so lightly that in several places there were minute cavities underneath the mass of larger and flatter flakes."

"A few small pieces of bone were found immediately beneath the layer; but above could be seen fine specimens, and smaller ones in abundance. . . . The flakes . . . are in most cases quite new and clean, always so on the lower side, very slightly discoloured . . . on the upper."

That the workman "worked on the spot is evident," from the facts above noted, and from flakes having been found in two, the pieces near together.

The author continues "I have been able to piece many of these flakes, and to demonstrate that the object sought was the manufacture of haches."

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\* *Journ. Anthropol. Inst.*, vol. viii. pp. 275-279.

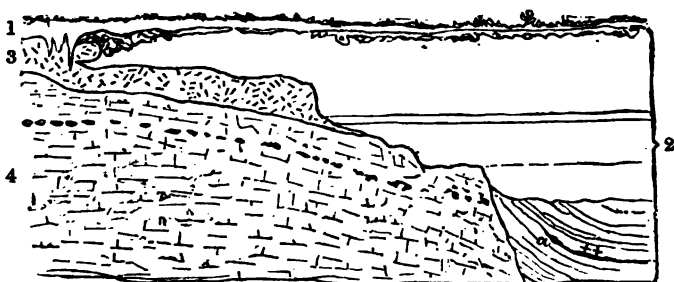
"All the parent stones have been derived from those found at hand and washed out of the cliff or fallen from it; not one had been rolled or dug out of the chalk."

The plate accompanying this paper shows a set of flakes "replaced in their relative positions around the hache, which lies within, forming a restoration of the block of flint as picked up on the neighbouring foreshore before being worked."\* I believe that this is the first record of a fossil workshop in England.

The accompanying figure (61) showing the position of the flake-layer is here reproduced by the courtesy of MR. SPURRELL, and of the Council of the Geological Society.

Figure 61. Section in the Chalk Pit at Crayford Brickyard, showing the Position of the Layer of Flakes. (F. C. J. SPURRELL.)

Scale 35 feet to an inch.



1. Soil.
2. Brickearth, with layer of flint-chips (a) and bones of Rhinoceros (+ +).
3. Chalk-rubble.
4. Chalk.

In 1882 we have the second paper from MR. WORTHINGTON SMITH, who gave the name "Palæolithic Floor" to the beds in the gravel that are more or less strewn with implements, which seem to have been made thereon, and who showed that the gravel of North London, from which but very few implements had been got, was really very rich in these records of early man, so much so that this author has said "It will be seen that, when, years ago, our English geologists were rushing from London . . . to visit the French drift . . . they were actually passing English positions equally rich with the French."

In his first paper† of this year MR. SMITH alluded to his discovery, in 1877, 78, of a working-place, floor, or old land-surface in the Valley of the Hackney Brook, and said:—

"When excavations are made in this valley, Palæolithic implements and flakes are disinterred, which in some instances belong to the Thames and are very ancient, in others to the Lea and probably somewhat less ancient, whilst a third set of implements belong to the Hackney Brook, and undoubtedly date from a very recent period of the Palæolithic age [corrected soon after]."

\* *Quart. Journ. Geol. Soc.*, vol. xxxvi. pp. 544-546, 548, pl. xxii.

† "Palæolithic Floors." *Nature*, vol. xxv. p. 460. (1882.)

The sharp examples belong to one stratum and the abraded specimens to a totally different one . . . The old banks" [of the Hackney Brook] . . . "are about four or five feet below the present surface, and on these banks (which I have examined . . . for three quarters of a mile, north and south at Stoke Newington, and Shacklewell) there lived at one time a considerable colony of Palæolithic men. The floor upon which this colony of men lived and made their implements has remained undisturbed till modern times and the tools, together with thousands of flakes, all as sharp as knives, still rest on the old bank of the brook just as they were left in Palæolithic times. In some places the tools are covered with sand, but usually with four or five feet of brick-earth; the sand . . . is full of the shells of freshwater molluscs."

"The floor is exposed in digging for the foundations of houses, it is sometimes visible as a dark line only at the base of the loam; at other times by the presence of a few inches of gravel; occasionally the traces of the floor are obliterated. All the implements from this floor are as sharp as on the day they were made."

In a later paper of the same year\* the following remarks occur:—

"During the present spring and summer several new . . . sections through the beds containing Palæolithic implements have been laid open at and near Stoke Newington. For the first time in my memory sections have been exposed which show the real age of the beds near the valley of the Hackney Brook; together with the older deposits on which they rest."

Speaking of the palæolithic floor he remarked "that that was really a working place where tools were made in Palæolithic times is proved by the fact of my replacing flakes on to the blocks from which they were originally struck." He corrected the earlier description of this floor (as belonging to the Hackney Brook), because "recent sections show that the Hackney Brook is quite modern, that it has cut its way through the Shacklewell gravels and only slightly disturbed them; in some places it has washed the 'Palæolithic Floor' quite away. The 'floor' really belongs to the Thames and the Lea" [all Thames] . . . At first the evidence seemed to indicate that the men worked on the old banks of the brook; it is now clear, however, that it was on the immensely older banks of the ancient Thames"

He then gave a section, the first published, through the floor, which is here reproduced (fig. 62) through his kindness. "The upper part . . . shows a section, facing the east, 300 feet long . . . It is taken through the gardens between Alkham and Kyverdale Road and south of Cazenove Road . . . north of, and close to Stoke Newington Common."

"To more clearly show the nature of the 'floor,' the 60 feet of the upper figure (where marked) is engraved below to a larger scale." (Fig. 63.)

"In the part illustrated (in fig. 63), the 'floor' is in duplicate. After the men had made their tools on the 'floor' where the lower D's occur, a slight flood of water covered up the tools with a thin coating of sand; the men then walked over the newly deposited material, and made other tools on the new 'floor.'"

He recorded having "many times seen [in the floor] such tender things as leaves, small pieces of wood and small crushed branches, generally . . . very friable."

"The non-waterlaid covering mass often disturbs the 'floor,' ploughs it up, and pushes underneath it. The twisting, contortion, and undulation of the material above the 'floor' seems to prove that it was laid down by moving ice from the north. This ice-deposited 'trail' is full of small whitish pebbles."

Fig. 64 "is a measured section through the 'floor' facing west . . . In the direction of the arrow . . . the 'trail' is seen pushing under and upheaving the 'floor.'"

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\* "Palæolithic Gravels of North-east London." *Nature*, vol. xxvi. pp. 579-582. (1882.)



Figure 62. Section in the Gravel near Stoke Newington, showing the *Palaeolithic Floor*. (W. G. SMITH.)

A. Bed of subangular broken flints, quartzite-pebbles, pieces of sandstone, a few pieces of quartz, and many small flint pebbles; seldom more than 5 inches thick, sometimes obliterated, or with only a single thickness of stones. The *Palaeolithic Floor*.

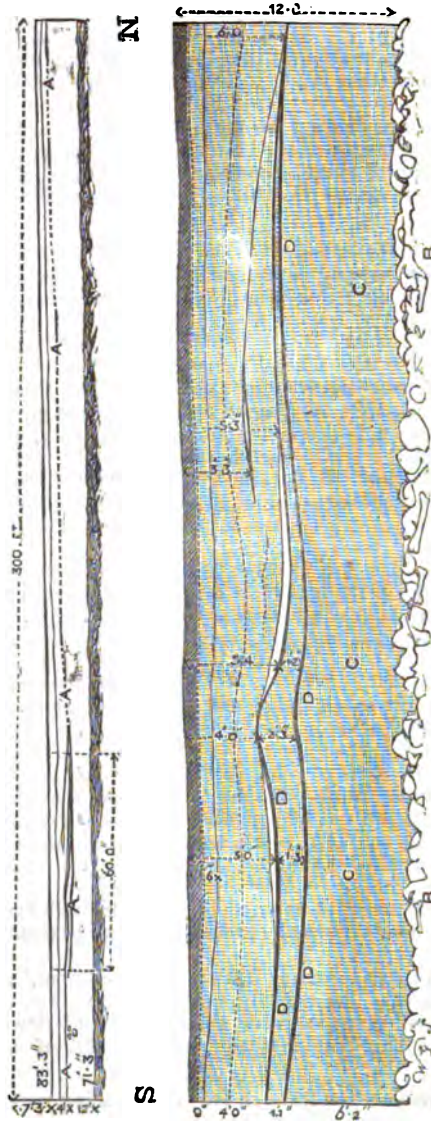


Figure 63. Details of Part of the above.

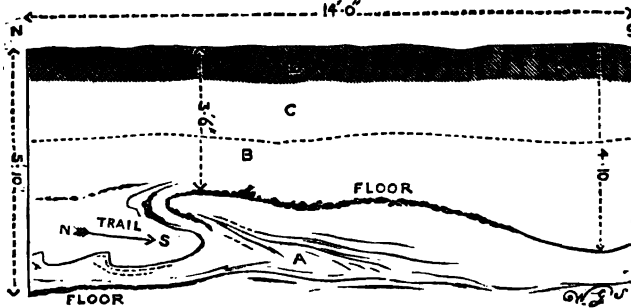
Soil. Where the darker tint is engraved, with neolithic celts and flakes. Sandy loam and loamy sand.

D. The 'Floor' with many unworn tools and flakes.

C. Fine, buff sand, often full of land- and freshwater-shells.

B. Gravel and sand, with rolled bones and abraded implements.

Fig. 64. Section near Stoke Newington, opposite that in Figures 62, 63.  
(W. G. SMITH.)



D. Soil.

C. B. "Muddy trail" with sand and a few stones.

A. Mass of London Clay and sand pushed under the 'floor.'

"Very near the sections here illustrated" (figs. 62-64) another cutting gave the section shown in figs. 75, 76.

"The 'Palæolithic Floor' . . . if present would be just above the horizontal (horizontal) bands of stratification, but the 'trail' at this spot has swept it away, it however occurs in a perfect state a few yards off."

In the following year Mr. SMITH continued the subject,\* and the following remarks on the age and character of the implements are from the paper first noted, but they appear also, sometimes in nearly the same words, in the other.

"Of the stone implements there are three distinct varieties, each belonging to a different geological time . . ."

"The oldest known tools are the rarest, and . . . can be recognized by the following characters:—they are generally lingulate, or club-shaped, with a heavy butt, often rudely ovate, never acuminate, generally large and very rude, frequently with a thick ochreous crust, and always greatly abraded.

. . . These old implements acquired their ochreous crust before they were buried in the gravel, as they occur amongst sub-angular lustrous flints . . . where only the implements and a few stray stones exhibit the ochreous crust . . .

In London, these old implements are generally found near the bottom of the twenty feet (or even thirty feet) excavations . . . All these older tools were made at a long distance from where they are now found . . ."

"In and near London lustrous and sub-abraded tools of medium age are commonly found at a depth of 12 feet; these tools show a distinct improvement in workmanship over the older ones. Most of the examples are lingulate and acuminate . . . somewhat large scraping tools are common. . . They were not made where now found, but have been carried by the drift for a short distance."

"Sometimes unfinished implements are found."

"Long after these two classes of tools were buried by floods of water deep in the gravel and sand, there lived a third race of palæolithic men, as far removed from the men who made the lustrous sub-abraded implements as these latter men were from the makers of the ochreous and highly abraded instruments. These newer tools are found at Stoke Newington at about 8 feet above the lustrous examples, and generally about 4 feet from the present surface. Denudation since palæolithic times has considerably altered the contours round north London, and the 'Palæolithic Floor' at South Hornsey, close to Stoke Newington, is 14 feet below the surface instead of 4 feet—this 10 feet has been removed in some places by the rains of centuries, in others by modern brickmakers and nurserymen."

"The newest palæolithic implements are as a rule not highly lustrous, but sub-lustrous, and often even dull; not abraded . . . but as sharp as on

\* "Palæolithic Implements of North-east London." *Nature*, vol. xxvii., pp. 270-274. "Primæval Man in the Valley of the Lea." *Trans. Essex Field Club*, vol. iii., pt. 7. pp. 102-147. Discussion, pp. xvi.-xviii. (1883.)

the day they were made . . . much smaller and lighter [in colour] than anything belonging to the two previous periods. . . . Oval implements with a cutting edge all round now appear . . . scrapers are common, not large and rough, but as a rule small and extremely neat . . . small knives, *i.e.*, flakes, with the edge or edges showing very neat secondary trimming, are common . . . As a rule every object is now neat, small, and fine."

"That these later implements are of a different age from the last is proved by the curious fact that the newer implements are sometimes re-made from the older ones, *i.e.*, retrimmed after the lapse of a vast period of time."

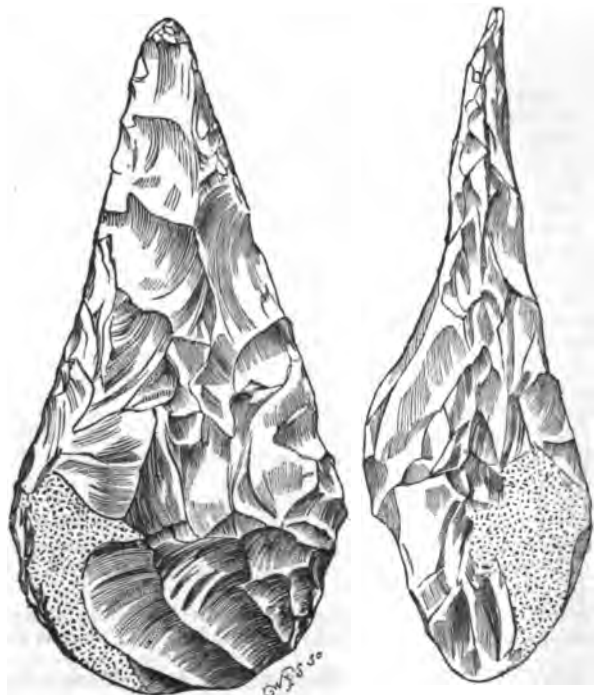
"The 'Palæolithic Floors' [in which these later forms occur], are not little isolated patches, but places extending for many miles."

"The newer implements and those of middle age, are innate with, and have belonged to the gravel from the first. The older implements are distinctly 'derived' like the cretaceous fossils commonly found in the gravel."

"There is apparently, but perhaps not really, a gap between each of these three palæolithic periods as there is apparently a gap between palæolithic . . . and neolithic times. Each older period however, has forms which foreshadow the forms which follow in succeeding periods even down to neolithic times."

MR. SMITH has most kindly allowed us to reproduce here, from the papers above noted, not only the illustrations of the sections described, but also those of implements, shown in Figs. 65-68, all originally in his own collection, but now in that of Dr. Evans. One of these is of much interest, not only as being the largest implement found on the "floor," but still more from having been found in detachments.

*Figure 65. Flint Implement from Lower Clapton. (W. G. SMITH.)*



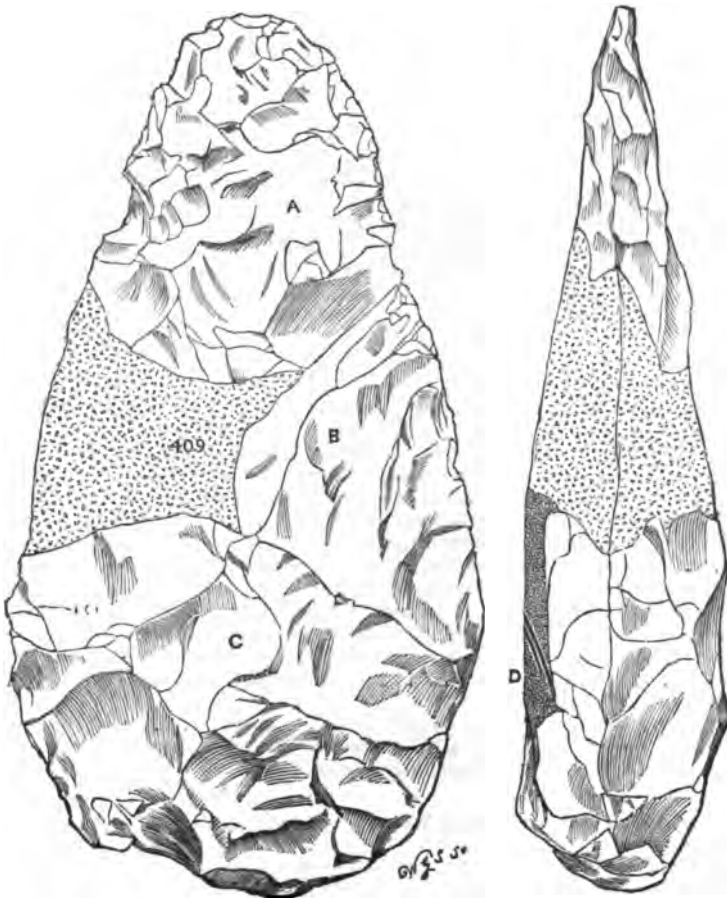
Half actual size.

Figure 66. Flint Implement (Chopper-form) from Stoke Newington. (W. G. SMITH.)



Half actual size.

Figure 67. Flint Implement from the Palæolithic Floor, Stoke Newington. (W. G. SMITH.)



Half actual size.

Shows scratches, on a patch of the original crust, at D.  
Found in three pieces, A, B, C, by two men, at different times and in different spots. The fourth piece (dotted) is missing.

The following further remarks are from the paper published by the Essex Field Club:—

"The *productive gravels* . . . are almost invariably those found between the 50 feet and the 100 feet contour-lines . . . there the implements will certainly be found. If one goes above the 100 feet line the implements become rare." Again, below the 50 feet contour, implements cease to occur, "and this fact seems to indicate that, when these lower gravels were deposited, Palæolithic men were not present."

Besides Hackney, and all around, the following implementiferous localities are recorded, on the western bank of the Lea. "Tottenham, Edmonton, Enfield, Forty Hill, Waltham, and Cheshunt. On the east bank . . . Leyton, Walthamstow," the other localities included belonging to the Thames below the Lea, "Plaistow, Stratford [etc.] . . . Wanstead . . . Leytonstone." Then "Barking, East Ham, and Ilford," which also belong to the old Thames gravel, not to that of the Roding, "and further east still, Grays Thurrock, Tilbury, Mucking, Orsett, and Southend."

In the same year Mr. SPURRELL said that "at Northfleet . . . five different forms of *hâches*\* were found; all made on the same spot, with great diversity of finish, at the same time that it continued to be a flaking floor." An implement is also recorded from gravel in the village of Erith, and a few from other places.

In another paper, of this year (but probably later)† he speaks of the Northfleet deposit as "a river beach, perhaps dry in summer and subject to floods;—though, subsequently to the deposition of the refuse, some of the ground has been pushed about by ice, yet the immense quantity of flakes (cartloads), and other signs of man's occupation, furnish abundant evidence that he lived near, and worked on the spot."

"These flakes are of all sizes, from over 3 lbs. in weight to a grain or two. Some are of great age, and have travelled far or lain long kicking about on the shingle, while others are as sharp as if made to-day."

In 1884 Mr. J. E. GREENHILL, who had been collecting for a few years, contributed a paper, on "the Implementiferous Gravels of North-East London," from which the following notes are culled‡:—"Excavations in Ayrstone Street, Stoke Newington, sometimes carried to a depth of 30 feet, resulted in the finding of 30 implements "besides an abundance of flakes, all in the same unabraded condition," in the bottom part of the pit, and it is concluded that this "floor" is a continuation of that at Stoke Newington Common. "Above this "floor," twenty distinct lines [planes] of stratification, i.e., twenty beds of clay and sand, may be readily distinguished, varying from three inches to three feet in thickness."

The same year Mr. SMITH published his paper "On a Palæolithic Floor at North-East London"§ in which he practically put together his former papers on the subject, and from which the following additional remarks may be taken:—"The best section of the "Palæolithic floor" . . . was exposed during the formation of the new roads on the north side of Stoke Newington Common, where Alkham, Kyverdale, Osbaldeston, and Fountaine Roads now are. The digging on this ground was continued . . . from 1878 to 1883, and the various excavations showed that about 4 feet from the surface there was . . . an immense accumulation of Palæolithic implements, including pointed and oval weapons and tools, large numbers of scrapers, hammer and anvil stones," etc. Sections here have been given in figs. 62-64, pp. 346, 347.

"In a five years' examination of excavations for new houses and drains (over a very limited area, and in erratic spots), more than one thousand implements . . . have been found . . . and simple flakes and cores . . . in hundreds of thousands."

"The implements have been found in such positions . . . that the idea is sometimes forced on one that all the makers of the implements suddenly left the place in fear of some impending danger."

\* Palæolithic Implements found in West Kent. *Archæologia Cantiana*, 1883.

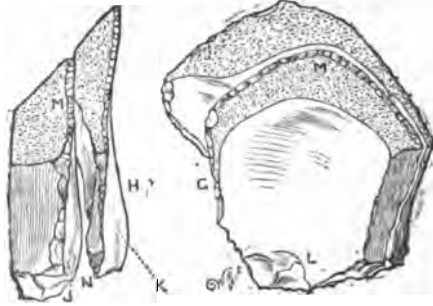
† *Journ. Anthropol. Inst.* 1883.

‡ *Proc. Geol. Assoc.*, vol. viii., no. 6, pp. 336-343.

§ *Journ. Anthropol. Inst.*, vol. xiii., pp. 357-384, pls. viii.-xxiii. (1884.)

Fig. 68 is "an example of two replaced flakes" of which he said "I found the lower flake two days before, and some distance from where I found the upper one . . . Both . . . show unmistakable signs of having been used as scrapers."

Figure 68. *Contiguous Flint Flakes, replaced, from the Palæolithic Floor, Stoke Newington.* (W. G. SMITH.)



G. Front of conjoined flakes.

J. K. Cones of percussion.

M. Worn upper edge of replaced flake.

H. Side of conjoined flakes.

L. Depression corresponding with cone of a missing flake.

N. Small intermediate piece, missing.

Of the men of the "floor," MR. SMITH said they were "probably, though savage, a peaceful . . . and intelligent community . . . The abundance of scrapers . . . shows that they scraped skins for clothing . . . Few of the implements are suited for weapons; nearly all are obviously tools."

Of the men of the next underlying gravel he said that they were ruder "yet, as we find undoubted scrapers . . . it must be conceded that the men knew how to rudely dress skins."

"It is not easy to form an idea of the men who made the oldest tools [in the basement-gravel]; they were savages of low degree, with instruments suitable only for hacking and battering. As no scrapers or knife-forms are to be found [in that gravel], the men probably knew nothing of dressing skins, and so went unclothed."

Of MR. J. A. BROWN's researches I believe that the first record is a mere reference in his "Sketch of the Geology of Ealing"\* and in a report of a lecture on "The Earliest Men of Ealing,"† but these are of no importance, as, in 1886, his discoveries were brought before the Geological Society‡ when he recorded "a well-formed implement . . . found . . . to the north of Longfield Avenue (125 ft. above O. D.) . . . beneath 14 feet of brick-earth and gravel," besides many implements at lower levels. MR. BROWN said that "the high-terrace gravels between 60 and 125 feet contain seams of black matter" and "that their position and relation to each other were more or less persistent . . . that a very distinct stratum was almost always apparent close beneath the brick-earth deposits, and that when the floor was not indicated by a seam of black matter, it was to be traced by beds of whitened pebbles and sub-angular fragments . . . The bleached surface . . . is often on the upper side only" and this seemed "to form a reasonable basis for the hypothesis that these seams represent old land-surfaces; and this . . . became to me almost a matter of certainty when unabraded implements &c., were found at levels corresponding with them."

"These old land-surfaces have been again and again broken up and disturbed, and with them these flint implements, which have become more or less abraded."

\* *Trans. Assoc. Municipal Sanitary Eng.* 1884.

† *Middlesex County Times*, December 1885.

‡ *Quart. Journ. Geol. Soc.*, vol. xlii., pp. 192-200.

"Three or four more or less distinct lines [planes] of former land-surface have been traced . . . One occurs at a level of 4 to 6 feet below the surface, a second at from 7 to 8 feet, and a third . . . at from 10 to 14 feet."

"It was not until the ground was excavated in the Creffield Road, Acton, at about 100 feet above O. D. that my views were entirely confirmed."

"In two small pits . . . within 6 or 7 yards of each other, the workmen discovered, close beneath the brick-earth deposits, and about 6 feet from the surface, about 400 implements, flakes and fragments, while at the second level of 8 feet, five or six specimens were met with, and at from 10 to 11 feet three specimens . . . It soon became evident that there had been a manufactory of Palæolithic implements on this uppermost floor, since they were often found together in nests, and they are all as sharp and unabraded as on the day they were made."

The following year Mr. BROWN brought out a special paper on this floor at Creffield Road,\* which chronicles some further finds as he says "on an area of about forty feet square . . . were found six hundred unabraded worked flints . . . in several instances I have been able to replace them in their original position and fit them together," from which it is clear that flakes are included in the number.

In his book of the same year† this author combines the subject-matter of his various papers, and gives a general account of researches on the question, a detailed "Description of the Forms and probable Uses of the Flint Implements found" (questions that cannot be entered into here), adding Dawley (Hayes), Hanwell, Turnham Green and Twickenham to the implement-yielding localities, with three plates of the local implements.

In bringing this section to an end it may not be out of place to examine its bearing on the question of negative evidence.

Had anyone said, fifty years ago, that anything would be found in Valley Gravel pointing to the presence of man on the earth at the time of the formation of that gravel, he would have simply been laughed at, and probably thought to be more or less of a lunatic. The negative evidence to the contrary was, or rather was thought to be, very strong, yet long before that time positive evidence of the fact had been recorded, though not exactly where geologists were likely to see it.

Again, when geologists had accepted, as a thing proven, the occurrence of man's implements in the River Drift, yet none such were known to geologists from the valley of our chief river, the Thames; though, as before, an occurrence had been noted, but had escaped attention. It was not indeed for some time that implements were found, except in a very few single cases; and for some time longer GEN. PITT-RIVERS' find at Ealing was the only plural one. Now implements have been found by hundreds, and flakes by thousands!

Years ago these River Drifts would have been classed as of Pre-Human age, without doubt. Now we know that they are not so.

Does not this show the danger of putting too much trust in negative evidence, when it stands alone, not backed even by circumstantial evidence? May not the same sort of thing happen with other conclusions, based solely on the absence of certain fossils?

\* *Proc. Soc. Antiq., Lond.*, 2 ser., vol. xi. pp. 211-216. (1887.)

† *Palæolithic Man in N.W. Middlesex* . . . 8vo. *Lond.* 1887.

## CHAPTER 21. RIVER DRIFT.

## REVIEW OF THE LITERATURE OF THE THAMES VALLEY DRIFT.

The older geologists treated all Drift as of one kind, and did not trouble themselves about such perplexing matters as its divisions and their classification. They accepted this varying set of deposits rather as a necessary evil, obscuring the beds below, and it is possible that some living geologists hold a not very different view. The literature of our subject does not therefore carry us back very far: indeed I can find no work distinctly claiming a river-origin for the wide sheets of gravel and brickearth bordering our chief river that dates from more than 50 years ago, when my first teacher in geology, PROF. MORRIS, took up the subject and, with his usual clearness, made the following remarks:—

“The valley of the Thames contains, in many parts, an old alluvial deposit, from which considerable quantities of brick earth are obtained, not only on the banks of the river itself, but also along the courses of those streams which empty themselves into it. In this deposit are found, rather abundantly, the bones of *Mammalia* associated with extinct and recent freshwater shells.” After describing sections at Erith, he goes on to say, of the fossils there found:—

“The remains [of mammals] . . . belong chiefly to the *Ruminantia* and *Carnivora*, the former of which occur abundantly, but the latter are rather sparingly distributed. The bones are seldom much rolled or broken, but are generally well preserved, and frequently perfect.” Of the mollusca it is noted that all “with the exception of two species, are still in existence; and the extinction of these two is probably confined to this country.” . .

“The living genera of some of the *Mammalia* are now only found in or near the tropical regions; but as their remains are presumed to have belonged to extinct species, and being accompanied by others which still inhabit the temperate zones, together with the evidence afforded by the *Testacea*, it is more reasonable to conclude that those species . . . were enabled to endure a climate not widely differing from the present, than to infer that these latitudes formerly possessed a higher temperature.”

“It may not be irrelevant to remark, that in these deposits we find scarcely any trace of vegetable remains.” . .

“The general occurrence of these fluviatile alluviums along the courses and margins of our present rivers, would lead us to infer that not much alteration has been effected in the physical features of the country since their deposition.”\*

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\* *Mag. Nat. Hist.*, n. ser., vol. ii. pp. 539, 544. (1838.)



In 1846 PROF. E. FORBES concluded, from the occurrence of *Corbicula fluminalis* and of a locally extinct *Paludina* [*Hydrobia marginata*], that the Grays beds "are probably contemporaneous in part with the marine strata of the red crag," and again spoke of "the associations of existing and extinct or southern forms of freshwater mollusca met with in the freshwater lake deposits of Essex . . . equivalent in part to the marine formations of the mammaliferous crag."\*

It seems somewhat strange that ten years after so clear a description as that above noticed, and by so good an authority as PROF. MORRIS, anyone should have ventured to bring forward the terraces of Thames Drift as examples of old sea-beaches, instancing the "fine equable slope extending from about 70 feet [above sea-level] at the end of the Crescent [Quadrant] in Regent Street, up to about 90 feet at the Regent's Park" as "exactly such a slope as a tide would form in its periodical ebb and flow," and strengthening the statement in the following words:—"A true tidal slope, though here and there slightly irregular, passes from about a line extended between Covent Garden and Golden Square, back to near Camden Town and Paddington. This is the beach so often referred to as terminating at about 90 feet—a fine example of it." It is hardly surprising perhaps that the author should add "But the grand terrace of this district is that extensive flat, composed of chalk debris containing round pebbles, which, crowning the bank at Greenwich Park, passes on to Blackheath and Sydenham in one direction, and to Dartford, if not farther, in the other";† though at that time it was known that the Blackheath pebble-bed was an old Tertiary deposit, quite unconnected with the Thames gravels, at Dartford or elsewhere. The above extracts seem to show how easily judgment may be warped, by too strong faith in a pet theory, to see things in accord therewith.

In 1848 MR. S. V. WOOD was inclined to think that the beds at Grays etc. "are probably the Freshwater equivalents to the Crag Periods,"‡ a view which however he gave up afterwards.

The next general statement dealing especially with our district (and we are not here concerned with descriptions of sections, which will find their place later on) is again by PROF. MORRIS, who, after describing a section at Brentford (see p. 397) says "From the general features, both physical and fossil, of this deposit, which has now been traced over a considerable area in the neighbourhood, I am inclined to consider it as resulting from fluvial action, and that at a period when a river, far more deep and extensive than the present stream [the Thames], flowed along the valley. Even allowing the base of the deposit to be level with

\* Memoirs of the Geological Survey, vol. i. pp. 393, 395.

† R. CHAMBERS. "Ancient Sea-margins, as Memorials of Changes in the Relative Level of Sea and Land." 8°. *Edin. and Lond.* (1848), pp. 23, 236, 237.

‡ A Monograph of the Crag Mollusca. Part [=vol.] 1, pp. v. vi. *Palaeontograph. Soc.*

high-water, a river of considerable depth must have existed, to have accumulated and arranged twenty feet of solid materials, and that not in a very violent manner, for scarcely any of the bones exhibit the least trace of attrition, most of them being perfect, and many belonging to the same individual; thus rendering it nearly certain that they could not have been drifted from any great distance, but were probably the remains of those animals which lived and died not far from the banks of that stream, where they subsequently became entombed in the same deposit with the fluviatile mollusca . . . it is generally along those valleys where the present drainage of the country is effected that we find the most extensive deposits of mammalian bones and recent shells; and consequently very little alteration can have taken place as regards the physical configuration of the country since the period of their deposition.”\*

In a somewhat earlier paper of the same year, but which deals with tracts beyond our borders, MR. GODWIN-AUSTEN made the following important generalizations on River Drifts as a whole, saying that :—“along every valley through which a river takes its course alluvia [that is, river-deposits of any sort, including gravel, &c.] are to be found at elevations such as the existing streams never attain. . . . The volume of the rivers of a district depends directly on the amount of moisture precipitated over it, and this depends on its elevation above the sea; so that to depress any given area will not tend to increase its rivers. . . . The conditions which alone will account for these appearances are obvious—the country, instead of having been placed at a lower level at the period of these broad alluvia, had a much greater elevation above the sea. . . . This condition . . . is applicable to every considerable river-course in the island, along every one of which we can find indications of the larger dimensions of the former rivers. The Thames and the Severn are striking examples.”†

The next year, in a paper chiefly referring to Norfolk, MR. J. TRIMMER said :—“In the Valley of the Thames there are two deposits of brick-earth and gravel; one containing mammalian bones, with land and freshwater shells identical with species now inhabiting the neighbourhood; the other destitute of them. The former are only found in the vicinity of the Thames and its tributaries, and at certain heights above them; the greatest distance at present known being about a quarter of a mile, and the greatest height above the present stream about 40 feet. These fluviatile deposits of gravel, sand, and loam are covered by others, in which a careful search . . . detected no fossils. The upper or non-fossiliferous deposits of the low grounds extend over the higher districts . . . . The lower deposits, and consequently the upper, appear, by the evidence of the granitic and

\* *Quart. Journ. Geol. Soc.*, vol. vi. pp. 203, 204. (1850.)

† *Ibid.*, pp. 92, 93.

other foreign detritus . . . to have been formed subsequently to the denudation of the erratic tertiaries" [Glacial Drift].\*

In another paper, relating to Kent, the same author enforces the last conclusion, and well remarks, as to the facts of the case, that "they can only be considered as partially established, until the superficial deposits of the valley of the Thames from its source to its mouth shall have been mapped, and their relations to the deposits of the glacial sea . . . shall have been satisfactorily determined. I know of no other mode of solving the question, than by laying down the variations in the deposits of that sea, with the same attention which has been bestowed on the older sea beds, which have hitherto been exclusively honoured with a place on geological maps."†

According to a table of the "Upper Tertiary Series," given this year, MR. GODWIN-AUSTEN seems to have taken the gravel of the Thames to be older than the Drift, or even than the Chillesford Clay of Norfolk and Suffolk, which last is now known to belong to the Crag Series.‡

In 1853 MR. TRIMMER described the high Dartford gravel, with which however he included the Blackheath Beds of Bexley Heath, as forming "a kind of terrace, about 150 feet above the tidal level," noting that it "has been cut through by the valley of the Darent, and by the minor inosculating valleys, which are destitute of streams," and adding that "the mammalian deposits of the valley of the Thames must be referred to a subsequent period."§

Two years later PROF. PRESTWICH described a section at Hackney (see p. 404), in which a bed of clay, with shells and parts of trees, was found in the gravel, and founded the following remarks on the facts then observed ||:—"The shells are all of recent species, and constitute a group which seems to indicate a deposit formed in shallow fresh water."

"The trees apparently did not grow on the spot, for no traces of roots *in situ* occur, although they probably flourished in the immediate neighbourhood; and as their remains are found dispersed irregularly throughout this clay . . . their presence here is not owing to the agency which spread the upper gravel over this bed, or to that which caused the extension of this deposit itself over the lower gravel—that is to say, it was neither the flooding of a previously dry surface by the waters from which the shelly clay was afterwards deposited, nor was it by the detrital sweep of the upper gravel over this . . . that the trees were destroyed. Their presence must, on the contrary, be due to some common cause in common operation during the whole period that the freshwater mollusks were living undisturbed in these waters. One

\* *Quart. Journ. Geol. Soc.*, vol. vii. pp. 25, 26. (1851.)

† *Ibid.*, p. 34.

‡ *Ibid.*, opp. p. 136.

§ *Ibid.*, vol. ix., pp. 287, 292.

|| *Ibid.*, vol. xi., pp. 108–110. (1855.)

cause might be occasional floods; although in that case we might have expected a greater change in the sediment, arising from the greater transporting power of the water,—the trees to have been more in seams, more of them showing uprooting, and more entire. Whereas the trees are in fragments, their branches and stems are sharply broken into short pieces, lying about without order . . . in a sediment showing little or no change. I conceive such a result to have arisen partly . . . from this cause, but probably chiefly from the occasional breaking off of boughs and the smaller stems of trees on the margins of these pools or meres, during gales of wind, which scattered them and the leaves over the surface of these waters, where they sank and got buried . . .”

“One of the principal points of interest attaching to this particular section is the clear indication of two gravel-periods separated by an interval of dry-land surface,—a character common throughout this district.”

In 1856 PROF. PRESTWICH in his paper quoted at p. 329, notices the unworn character of the bones from the gravel at Taplow, and adds :—“Nor does the gravel itself afford any evidence of long-continued movement or of much wear. If we eliminate from it the flint-pebbles derived from the tertiary beds and the pebbles of the older rocks derived from the new red sandstone, we have a residue of subangular flints which exhibit extremely little wear—nothing like that which would result from long-continued river or shore action—and it is necessarily this residue which gives us the true measure of wear and tear which the mass has undergone.”\*

In the following year the same author published a general and popular account of our River Drifts, from which the following extracts are taken.† Referring to the general composition of the gravel, and alluding to the occasional occurrence of pebbles of quartz and of various old rocks, he concludes that “the great and preponderating mass of flint debris from the chalk hills, and of sandstone and chert from the greensand hills of Surrey, leaves no reasonable doubt that the main bulk of the gravel of Clapham and of London has been derived and transported from the Surrey downs and the Sussex hills.” Probably however, our author would now somewhat modify that conclusion, and would allow that the cherty fragments from the Lower Greensand (which are really of somewhat exceptional occurrence) may have been brought in by tributary streams, or derived from still older gravels, whilst the main bulk of the materials has come down in the direction of the present main valley.

Referring to the chief constituent of the gravel, flint-fragments, and to the accompanying perfectly rounded flint-pebbles, derived from old Tertiary beds, he observes that “it is not possible, that the action which left the greater number of the flints in their

\* *Quart. Journ. Geol. Soc.*, vol. xii. p. 182.

† *The Ground Beneath Us* . . . the Geology of Clapham and the Neighbourhood of London generally . . . 8°. *Lond.*, pp. 13, 15, 17–19, 21, 29. (1857.)

rough subangular form, could have formed these round pebbles, or that the action which produced the latter, could have left the other flints so slightly worn."

Reviewing the different theories that have been brought forward to account for the origin or transport of the gravel, our author shows that the earliest, the diluvial theory, (involving "the rapid and transient passage of a body of water"), is not in accord with the facts, for "if the action were so violent, how is it that we nevertheless occasionally find in the drift . . . around London the most delicate and friable land and freshwater shells, perfectly uninjured?" As to the theory of river-origin he says "the gravel, as a whole, seems too widely and irregularly spread, and too little worn to have been formed by such means," another conclusion which probably he does not now hold. With regard to the two other theories, of sea-currents and of transport by coast-ice and by icebergs, he points out that in both "the absence of contemporaneous marine organic remains presents the same difficulty."

Of the contained fossils PROF. PRESTWICH says that those "found, although at distant intervals, in the gravel of the neighbourhood of London, form a most remarkable and interesting group . . . and suggest many curious climatal and geographical questions. The bones of the land animals are sometimes mineralised, but they are far more generally little altered from their original state, except that, having lost their animal matter, they have become soft and fragile, as have also the associated shells." He alludes to the occurrence of bones belonging to more or less arctic species, such as the reindeer and the musk-sheep, and says that the mammals of the period "belong to families now widely dispersed and severally confined to various latitudes, from the tropics to the torrid zone, but then fitted to inhabit a common land." Of the mollusca it is said that "although some . . . might live in a climate warmer than that of England, still, looking at the entire group, they are such rather as we might expect to find in a colder than in a warmer climate than our own. Taking this evidence in conjunction with that . . . with respect to the various animals [mammals], it is probable that . . . the temperature of this part of Europe . . . may not only have been no higher than at present, but that the cold of winter at all events may have been far more severe, resembling in that respect an arctic rather than a temperate region."

The same year MR. GODWIN-AUSTEN, in describing "the Newer Tertiary Deposits of the Sussex Coast," made the following remarks on the local brickearth, which clearly he would have applied to that of our district, for the most part at least:—"With reference to the conditions under which the brick-earth has been formed, it may be stated generally, that it is a subaërial deposit. In every instance, in every country, it partakes of the nature of strata immediately contiguous. . . . Its most usual character is that of the wash of a terrestrial surface under a far greater amount of annual rain-fall than we have at present. . . .

In any speculations respecting the origin and circumstances of the brickearth-deposit, it must be constantly kept in mind that the present physical features are not those of the period when the brick-earth was deposited.”\*

In 1858 DR. H. FALCONER, in an abstract of a paper on Fossil Elephants in England, “considered the fluviatile deposits of the Valley of the Thames, in relation to their Elephantine remains; especially at Grays Thurrock and Brentford. At the former place the author recognises the true pliocene assemblage . . . but the group of mammals found at Brentford, according to the published determinations, indicate the close proximity of both the pliocene and post-pliocene faunæ at different levels in the same section. The Grays Thurrock deposits, and the lower beds at Brentford were inferred to be of an earlier age than any part of the Boulder-Clay or Till.”†

After this date researches on our River Drifts were greatly stimulated by the acceptance of M. BOUCHER DE PERTHES’ views as to the occurrence, in like beds in France, of flint implements, made by man, in place (see p. 338).

Although PROF. PRESTWICH’s first paper on this subject does not refer to our district (being concerned indeed chiefly with the Valley of the Seine, and little with England) yet it contains some general remarks that may well be quoted here:—“It is probable that subsequently to that phase of the Glacial period marked by the Boulder Clay, the area of dry land became more extended, and on it there lived the *Elephas primigenius* and *E. antiquus*, *Rhinoceros tichorhinus*, *Hyæna spelæa*, with species of *Deer*, *Horse*, and other animals, mostly of extinct, but some of species not to be distinguished from the recent; whilst the waters of both sea and land were tenanted almost exclusively by shells of recent species still common in this and adjacent countries. The remains of this old surface we find in deposits, which everywhere contain a similar group of organic remains, and occur mostly in old valleys or at moderate elevations. They are never overlaid by other fossiliferous deposits, and I believe them all to belong to a state of things which immediately preceded the present order. One feature of these deposits is, that although closely related to the present configuration of the surface, yet they are always more or less independent of it. They are often near present lines of drainage, yet could not, as a whole, possibly have been formed under their operation.” The “lower-level deposits are, although not to the same degree [as those of the higher level], quite beyond the agency of present river action, and are independent of recent changes. It is probable that the various beds, although on these different levels, belong to the same general period, and may be nearly synchronous.”‡

\* *Quart. Journ. Geol. Soc.*, vol. xlii. pp. 63, 64. (1857.)

† *Ibid.*, vol. xiv. p. 83.

‡ *Phil. Trans.*, vol. cl. pt. ii. pp. 302, 303. (1860.)

In 1863 SIR C. LYELL said:—"I long ago suggested the hypothesis, that in the basin of the Thames there are indications of a meeting in the post-pliocene period of a northern and southern fauna." . . .

"We may readily conceive that the countries now drained by the Thames . . . were . . . on the borders of two distinct zoological provinces, one lying to the north, the other to the south, in which case many species belonging to each fauna endowed with migratory habits . . . may have been ready to take advantage of any . . . change in their favour to invade the neighbouring province." . . .

"In attempting to settle the chronology of fluviatile deposits, it is almost equally difficult to avail ourselves of the evidence of organic remains and of the superposition of the strata, for we may find two old river-beds on the same level in juxta-position, one of them perhaps many thousands of years posterior in date to the other. I have seen an example of this at Ilford, where the Thames, or a tributary stream, has at some former period cut through sands containing *Cyrena* [*Corbicula*] *fluminalis*, and again filled up the channel with argillaceous matter . . . It may happen, as at Brentford and Ilford, that sand-pits in two adjoining fields may each contain distinct species of elephant and rhinoceros."

And he remarked that "we must suppose that the basin [valley] of the Thames and all its fluviatile deposits are post-glacial, in the modified sense of that term; i.e. that they were subsequent to the marine [Glacial] drift."\*

PROF. PRESTWICH'S great paper, on the "Deposits containing the Remains of Extinct Mammalia and Flint Implements," appeared in 1864, having been preceded by a lengthy abstract two years earlier,† and from this paper come the following extracts:—

"I could not admit the possibility of river-action, as it now exists, having in any length of time excavated the present valleys and spread out the old alluvia; neither was it possible to admit purely cataclysmic action in cases where the evidences of contemporaneous old land-surfaces and of fluviatile beds were so common. But with river-action of greater intensity, and periodical floods imparting a torrential character to the rivers, the consequences of the joint operation are obtained, and the phenomena admit of more ready explanation." . . .

"In these valleys one series of gravel-beds is spread over more or less of their breadth, rising occasionally on their flanks to a height of 10 to 30 feet, and ranging throughout their length, though constantly . . . hidden by recent alluvial deposits. The lower ranges of hills which flank these valleys on either side are occasionally capped by other similar gravels, but which, so

\* The Geological Evidences of the Antiquity of Man. 8°. Lond., pp. 156, 158-160, and in later editions, with some verbal alterations.

† *Phil. Trans.*, vol. cliv. pt. ii. pp. 247-309. *Proc. Roy. Soc.*, March 27, 1862. Pages quoted, 250-252, 255, 265, 270, 271, 273, 274, 281, 283, 286, 287, 295.

far from being continuous like the lower-level beds, occur at intervals, and there are long tracts without any such drift. The higher gravels are also generally separated from the lower gravels by a bare sloping surface, whilst they rarely extend far from the valley and never reach the tops of the higher hills. The two series bear nevertheless a definite relation one to the other. They both consist of *débris* derived from rocks in the valleys through which the present rivers or their tributaries flow . . . and there are cases of minor intermediate terraces."

"With regard to the valley of the Thames the structure is far more complicated [than that of some other valleys], from the circumstance of there being . . . a wide-spread set of higher or hill-gravels, of marine origin, presenting a very close similarity to some of the valley-gravels."

"That the formation of the higher terraces can be owing to the action of the present rivers [as seems to have been suggested] is clearly impossible under existing conditions; for they are far above the level reached by the rivers at the highest floods."

The "low-lying gravels, from their general continuity and their slight difference in level, leave us no doubt as to their relation to the existing valleys."

"The main points of difference . . . are the greater thickness of the low-level gravels, their more uniform bedding, the more common presence of beds of sand and fine gravel with oblique lamination [current-bedding], and the absence generally of contorted strata . . . On the whole these lower gravels have a more washed, sorted, and worn character than the upper gravels."

"The brick-earth is intimately associated with all the valley-gravels and is contemporaneous with and dependent upon them from the beginning to the end of the series."

"I conceive the Loess [= the brickearth] to be the result of river-floods."

With regard to the high-level gravels "if we had to depend only upon the organic remains for decisive evidence of the nature of the climate of the period, . . . we might fail to arrive . . . at any exact or positive conclusion. All the recent species are . . . now to be found within the limits of the temperate zone, but they appear to agree better with the fauna and flora of its northern than of its southern provinces; the Fossil Mammalia may also . . . be considered to have inhabited cold countries; so that there is a balance in favour of the probability of a severer, but not of an extreme climate. On the one hand, we are restricted in the degree of mean winter cold by the presence of trees; . . . on the other, we are restricted in the degree of heat by the range of the Reindeer and the absence of southern forms."

With regard to the low-level gravels, from "the great bulk of the species, . . . being common to both levels of gravel, we may presume that no very important change in the mean temperature then took place," any change being in the direction of less rigour.



Referring to the deposits generally, the "conditions, taken as a whole, are compatible only with the action of rivers flowing in the direction of the present rivers, and in operation before the existing valleys were excavated through the higher plains, of power and volume far greater than the present rivers, and dependent upon climatal causes distinct from those now prevailing . . . The size, power, and width of the old rivers is clearly evinced by the breadth of their channel, and the coarseness and mass of their shingle beds." . . .

"It is further evident, from the presence in the terrace gravels of large blocks, often but little worn and transported from considerable distances [though these are rare in the case of the Thames], together with much sharp and angular smaller debris, that there was some other power in operation besides the ordinary transporting power of water. . . . The only cause adequate to produce these results is, I conceive, the action of river-ice." . . .

"Two agents, floods and ground-ice, would affect chiefly the river-channel. There is another agency which would co-operate in that direction, but would affect more especially the banks and shores of the river; that is, the freezing of the ground and the rending of rocks by great cold" . . .

It seems to me that this paper clearly explains the processes that brought about the results we now see: the existence of a more powerful river, flowing through a valley with a broader bottom than that of the present river, and depositing a great, though thin, sheet of gravel: the deepening of the valley, the river cutting through that gravel, and leaving masses of it above the level of the more restricted stream, which, in its turn, deposited another and lower thin sheet of gravel: the continuance of the process, and the gradual evolution of the present stream, of decreased size and power. As far as I can see nothing that has been since observed or written has shaken the conclusions of PROF. PRESTWICH.

In 1866 MR. S. V. WOOD, Jun. treated, in some detail, of "the Structure of the Thames Valley and of its Contained Deposits,"\* saying that the partial gravel-terraces along the Thames "though irreconcilable with any cutting down of the valley from higher to lower levels, are in no way at variance with the unequal action of an upthrow," and coming to the conclusion that the gravel and brickearth series consisted of four members, as follows, from below upward:—

*The Lower Brickearth*, which underlies and is unconformable to the "Thames Gravel." This occurs at Ilford, near Erith, and at Wickham Lane. It seems to have been a very limited deposit.

*The Thames Gravel*. A great sheet.

*The Upper Brickearth*, which has a large spread, though but comparatively thin, and rests on the gravel.

*The Grays Brickearth*, formed after upheaval and denudation of parts of the older beds.

To this succeeded "The Forest and Peat" of the marshes.

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\* *Geol. Mag.*, vol. viii. pp. 57-63, 99-107.

MR. WOOD held that we have "no signs of any line of drainage conterminous with the valley through which the Thames now finds its way from London to the sea, until after a series of diverse conditions, and until a most recent date,—that of the Marsh clay . . . the *present* valley of the Thames is a creation subsequent to all the deposits which it contains that are older than the Marsh clay." A conclusion with which probably few geologists will agree; and the same may be said of the opinion that "the fault which at Sea Reach opened the Thames river to the sea indicates a throw of between three and four hundred feet," that fault being, I believe, inferential only.

His views of the formation of the valleys are as follows:—

"That the original valley, formed . . . by denudation during emergence from the Upper Drift [Glacial] sea, began (after passing through the Bagshot sand and London clay alone, between Windsor and London) to cut down on the east of London to the Lower Tertiary sands . . . and that the line . . . curving south-eastwards, and passing across the extreme south-west of Essex, made its way to the sea in the direction of the eastern half of the Weald" . . .

"That in the trough so formed, and after its complete excavation, the . . . Lower Brickearth . . . was accumulated. . . . That after this the valley underwent a considerable depression, by which the sea was admitted . . . by which an uniform sheet of . . . gravel . . . was deposited . . . And that . . . a change ensued by which the sources furnishing the gravel were cut off, the mud brought down by the surrounding streams . . . being . . . allowed to subside." . . .

"That the south side of the valley was then subjected to violent convulsions, which broke up the surface, and caused an extensive denudation of all the three deposits," etc.

"The water depositing the Thames gravel was that of a strait connecting the Post-glacial sea of the west, beyond Reading, with the same sea over the Weald, which was then denuding the Wealden area."

With the above views, as far as I know, no geologists have expressed agreement. After the simple explanation of PROF. PRESTWICH they seem too complicated and involve too many hypotheses. As to the suggested divisions of the series MR. WOOD satisfied himself two years later that it was an error to regard the brickearth of Erith and Crayford as older than that of Grays, and that both belonged "to the lower or fluvatile terrace of the Thames gravel formation,"\* and in 1874 he allowed that the Ilford bed was "identical in age with the *Cyrena* beds of Grays Erith and Crayford."†

MR. WOOD continued the subject in a later paper of the same year "On the Structure of the Valleys of the Blackwater and the

\* *Geol. Mag.*, vol. v. p. 584. (1868.)

† *Geol. Mag.*, dec. ii., vol. i. p. 392.

Crouch, and of the East Essex Gravel . . .”\* This gravel reaches into Kent, “fringing the Medway between the Nore and Rochester,” and “intimately resembles the Thames gravel. It also presents a complete parallel to that gravel, in being capped in parts with a brickearth, into which it passes upwards.” The likeness in question is hardly surprising to those who take this gravel to be simply an easterly continuation of that of the Thames, following, as it does, in part the present valley, and in part the probable former easterly or north-easterly extension thereof.

The present position of the East Essex Gravel is thought to be due to disturbance, “the Chelmer River and Blackwater Estuary form a dividing line, on the south side of which the entire block of country, lying between this . . . and the mouth of the Thames, has been elevated without any corresponding elevatory movement having taken place on the north side, but rather the reverse.” The reasons for invoking this disturbance seem however to be purely theoretical; no evidence of it was found in making the Geological Survey, though of course, in a tract where a thick mass like the London Clay forms the substructure, and in part the surface, many small disturbances may exist without giving any sign at the surface. I must indeed confess my inability to follow some of the reasoning in this paper; for instance when it is said that the lower part of the valley of the Crouch “consists of a rectilinear fissure which has passed at right angles through the older trough occupied by the East Essex gravel, and through that gravel itself,” and that the upper part of the Crouch Valley can have once been part of the Blackwater Estuary. Certainly the Crouch cuts through what seems to me to be simply old Thames Gravel, between Paglesham and Burnham, as might be expected of a former tributary; but of fissure I can see no evidence.

It seems to me that MR. WOOD, who did so much to throw light on the structure of the Glacial Drift of the eastern counties, has, with these later beds, been somewhat led astray by over-theorising. Surely when a simple explanation accords with observed facts, it is needless to go further afield for a complicated and absolutely bewildering one.

In 1867 PROF. W. B. DAWKINS discussed “the Age of the Lower Brick-earths of the Thames Valley.”† He says that the uppermost bed at Ilford “by the confusion of its bedding, the admixture of clay with sand and gravel, and the presence of pebbles of chalk [? decomposed flint] and of large transported boulders of greywethers and of flint, is proved beyond all doubt to be of glacial origin—to have been carried down by the ice, on its melting, upon the eroded top of the fluvatile deposits below.” If so it seems to me that it will not be difficult to prove that most

\* *Geol. Mag.*, vol. iii. pp. 348–354, plate, and, under a different title, pp. 398–406. (1866.)

† *Quart. Journ. Geol. Soc.*, vol. xxiii. pp. 91–109.

surface-deposits are glacial. Naturally a like opinion is expressed as regards Grays, where the top bed of the Drift "as shown by the irregular size of its pebbles, its tabular flints, its contortions, and its irregular deposition, owes its presence to ice in some form."

In his description of the Erith section an error has unfortunately occurred, there being really no Eocene beds in place in the section, as was noticed in 1872;\* but this does not affect the arguments of the paper.

That the brickearths of the various places are of the same geologic age is perhaps the only stratigraphic conclusion in which one can agree with our author.

Of the mammalian remains he says that "the presence of *Elephas priscus* and *Rhinoceros megarhinus* indicates the affinity of the group to the Præglacial deposits of Norfolk and to the foreign Pliocene strata. The tichorhine and leptorhine Rhinoceroses, on the other hand, point towards deposits of clearly defined Postglacial age . . . The beds under consideration are also as remarkable for the absence of some as for the presence of others of the Pleistocene mammals . . . From these premisses one conclusion inevitably follows:—that the Lower Brickearths . . . as affording remains of mammals in part peculiar to the forest-bed of Norfolk . . . in part to the Post-glacial deposits . . . occupy a middle point in time between the two."

PROF. DAWKINS then combats the views of PROF. PRESTWICH, as "diametrically opposed by the mammalian evidence, and which if proved to be true would overthrow the Palæontological value of the labours of all the Tertiary mammalogists"; surely a strange argument to oppose to those views, and one that ignores stratigraphic evidence. "If all the superficial deposits in the valley of the Thames have been left by its waters at different levels above the present stream, those levels will give the relative antiquity of the beds of loam, sand, or gravel, *provided that the land has remained stationary*. But if the land was elevated in one place and depressed in another, as we are bound to admit was the case throughout the Pleistocene period, then the evidence of level is of no importance . . . or if we suppose a valley with a river flowing through it to be depressed beneath the surface of the sea, the higher marine deposit may even be *younger* than the lower fluviatile one."

The second of these remarks seems based on the supposition that we are dealing with the whole Pleistocene period over the world at large! But we are not, and for the argument to have any value it must be shown that these unequal oscillations of land have taken place in that part of the Thames Valley with which alone we are concerned, and no evidence of the sort is given. The argument as to the higher marine deposit does not hold because there is no such deposit in this valley! The instance given of a

\* Memoirs of the Geological Survey, vol. iv., p. 118. Reproduced above, p. 141.

marine Drift overlying a late freshwater deposit is quite beside the mark, for the so-called "Forest Bed" is distinctly seen to underlie the Glacial Drift: there is no doubt about the stratigraphic position of the bed, and were remains of many presumed Postglacial mammals found in it even that would not affect the value of the direct stratigraphic evidence.

The author alludes to the fact of Boulder Clay being found in the bottom of the Roding Valley (high up in its course, far from the Thames), and in a like position in the valleys of the Blackwater and of the Colne; but how this can "prove that the main features of the country were sketched out before the Boulder-clay period" and that the Thames "was excavated in Præglacial times," is by no means apparent. The fact is that the higher parts of some Essex rivers are placed in the great sheet of Boulder Clay, through which they have in many places been unable to cut; but that does not prove that a vastly bigger river could not have done so, especially as those very streams have all succeeded in the work lower down their courses. (See also MR. WOOD'S remark, further on.)

The conclusion to which PROF. DAWKINS comes, that the Lower Brick-earths of the Thames are older than the Glacial Drift seems to me to be unwarranted by the physical evidence, which points the opposite way, to depend only on the occurrence of the remains of a few mammals, and to ignore the rest of the palæontological evidence.

It is satisfactory to find the REV. O. FISHER saying, in regard to the "trail," or disturbed top bed at Ilford and other places, "I do not believe that any argument as to the age of the Brick-earth can be founded on this deposit, except—what would be self-evident without it—that it is older than the latest denudation of the surface.\*"

A more general paper by MR. WOOD, published the same year, refers largely to the Thames Valley.† In this, after referring to the arc-like or curvilinear disturbances in which he believed that the chief watersheds of the East of England originated, he concluded, from the Boulder Clay of southern Essex being just like that found further north, that "its abrupt termination on the northern brow of the Thames valley . . . is to be ascribed to denudation only," adding "there is but little room to doubt its having spread over the counties of Surrey and Kent." If so a singularly clean sweep has been made, no trace having yet been met with south of the Thames.

The views expressed in his paper of the year before are enforced, and, speaking of the southern ending of the gravel of Richmond Park, he adds that "the Wealden upthrow . . . succeeded the denudation of the gravel," with which probably few geologists will agree.

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\* *Geol. Mag.*, vol. iv. p. 194. (1867.)

† *Quart. Journ. Geol. Soc.*, vol. xxiii. p. 394. (1867.)

The conclusions deduced from the presumed difference of age between the Erith and the Grays brickearths can be passed by, as the author gave up the idea soon after (see p. 363). When however he speaks of "the disturbances that broke up and elevated the Thames gravel" one must join issue with him, especially when he goes on to speak of "the gravel being elevated on one side of the principal rectilinear throw as much as 116 feet above the present sea-level and thrown down to almost as great a depth below the Plumstead and Erith marshes." These disturbances are purely theoretical: there is no evidence for them on the ground, and there is no such deep-seated Drift Gravel as that mentioned as occurring below the marshes. In mapping the Thames Drifts I could see no sign of such faulting as is here alluded to, nor can I see reason to invoke disturbance because gravel may sometimes occur exclusively on one side of a valley, whether of the Thames or of the Lea.

In a concluding note the author very properly alludes to the fact, apparently overlooked by PROF. DAWKINS, that because a valley happens somewhere to run along one of the Boulder Clay depressions that are not uncommon, it does not follow that the whole valley is Pre-Glacial. As the Boulder Clay scoops into underlying formations it is likely that a valley may somewhere run along one of these scoops. Nor does it seem that PROF. DAWKINS,\* in his answer to this note, has advanced his case, especially as by "valley" he means "the area below a line drawn from one watershed to another," a meaning which, as far as one can understand it, would make the Thames Valley a synonym for the whole Thames Basin, with its manifold valleys, and would therefore make the term simply useless. The repetition of the argument that if the fossiliferous Thames Valley deposits are Post-Glacial "the evidence of fossils characteristic of Pliocene mammals [? formations] . . . is useless in classification" may show only that the evidence in question is doubtful.

MR. WOOD made a counter-reply in 1868.†

The next year there appeared a long paper "On Quaternary Gravels" by MR. A. TYLOR, in which he referred largely to the valley of the Thames, and the following are some of his conclusions:—‡

"The evidence of numerous sections teaches us that, prior to the deposition of the gravel, there was a land-surface smoothly denuded by rain and streams so as to form a perfect system of principal and minor valleys, the ground sloping from higher to lower points, so as to admit the rainfall to flow with the minimum of obstruction into the side-valleys, and thence into the ancient Thames. The subsequent deposition of the gravel-series did not in any way alter old lines of drainage; but where concavities existed, the new deposit had a tendency to fill them up

\* *Geol. Mag.*, vol. iv. p. 365. (1867.)

† *Ibid.*, vol. v. pp. 42-44.

‡ *Quart. Journ. Geol. Soc.*, vol. xxv. pp. 58-61. (1869.)

with a thicker stratum of material than was spread over the general surface of the chalk or clay."

"Except where the old river-channels and concavities are filled up, the contour and the modelling of the upper surface of the gravel-series resembles that of the clay or chalk on which the lower gravel rests, and is perfectly adjusted to carry off the rainfall occurring in the later part of the gravel-period into the ancient Thames without any impediments. The contour of the land is such that it could only have reached its present form by pluvial and fluvial action, and not by marine denudation. Many of the minor valleys in which gravel and brick-earth were deposited with each flood in the Quaternary period are now dry. After the heaviest rainfall in recent times there is not sufficient force of water to remove vegetation, so as to make any change in the present surface."

"We are therefore justified in stating that the character of the denuded surface of the London Clay and Chalk above the level of the Thames is evidence of the occurrence of an enormous rainfall in the commencement of the gravel-period, and that the character of the surface-deposits of gravel [with boulders as large as in any other part] is evidence of nearly as much rainfall at the close of that period."

"With a rainfall such as we now have, it would be impossible that such widely-extended gravel-beds could be spread over an extensive area, and reach to a height more than 150 feet above the level of the Thames. It is equally impossible for the present volume of the Thames to have produced fluvial beds at all equivalent in size to those of the ancient Thames." Our author seems here to assume that all the gravels were deposited after the valley had been excavated to its present shape, which is most unlikely (see EVANS, *post.*)

"The condition of the beds which rise above the 50-feet level, points rather to pluvial than fluvial action."

With Mr. Tylor's conclusion "that no marked changes of level occurred during the gravel-period," one can hardly agree; but he seems to consider only "elevations of the land," whilst it seems likely that the lower terraces, in a narrowing valley, point to slight depression, with consequent lessening of rainfall and decrease of strength of streams.

He goes on to say that "the series of Quaternary strata generally commences with a coarse gravel, a few feet thick, eating into the chalk or London clay in which it lies, and mixing up the clay or chalk with the gravel."

"The coarse gravel often passes into coarse sand, and is evidence then that the movement of the water at that point was not sufficiently rapid to transport gravel, or that there was no gravel present to be deposited."

"I have not observed any finely bedded clay or loam in contact with the surface of the chalk or London clay . . . and this appears as if the movement of water over the surface of the

clay and chalk had been generally rapid at the commencement of the Thames deposits."

"Where concavities in the chalk and London clay exist in the neighbourhood of the Thames, and in its side-streams, and are so situated as to be favourable for quiet deposition, the lowest bed of gravel or coarse sand sometimes contains fossils derived from the Eocene beds, and rolled Mammalian remains of a later period. It is succeeded [below London] by a series of laminated clays and false-bedded sands, from 20 to 30 feet in thickness, with water-worn materials, and containing fluviatile and land shells, tranquilly deposited with Mammalian remains (only occasionally rolled)."

"Non-fossiliferous gravels are often clearly contemporaneous with these fluviatile brick-earths. If on the same horizon, they are sometimes interstratified with the fossiliferous beds; but the non-fossiliferous gravels reach to much higher levels [when however they are probably not exactly contemporaneous with the brick-earth at lower levels], and are deposited at much steeper angles, and contain materials not perfectly washed or water-worn. They include masses of Thanet sands, of plastic clay, and of the fossiliferous bands of the Woolwich series, buried in great unrolled masses in the gravel, as well as water-worn masses of Druid Sandstone, derived from strata very near the spot of deposition. These materials were evidently washed in by floods, not confined to the valleys, but passing over the whole surface of the land, tearing up the ground and carrying it to lower levels in the valleys."

MR. TYLOR then speaks of the ancient river-deposits of the Thames being "generally covered by an upper bed of well-rolled gravel," not more than 10 feet thick, and often only 3 or 4, which "lies on the frequently eroded surface of the stratified brick-earths and clays of the middle part of the . . . series." This thin bed of "pebbles, enclosed often in a stiff brown clay, but sometimes in sand or loess, extends from the river-banks to near the tops of the hills over all the other parts of the series of gravels, and often over the London clay and chalk." If our author means, as seems to be the case, that one and the same bed occurs over the top of nearly every part of the River Drift, from the lowest to the highest terrace, I think that few geologists will now agree with him. Is it not more likely that like conditions, occurring toward the end of the formation of each successive terrace of gravel, have led to the top part of each terrace being of like character? though MR. TYLOR himself notes the varying character of the matrix of the stones, from clay to sand.

In the same volume is an important paper by PROF. DAWKINS "On the Distribution of the British Postglacial Mammals,"\* to which we are indebted for a detailed and authoritative record of these fossils, the result of ten years work on the subject. In this

\* *Quart. Journ. Geol. Soc.*, vol. xxv. p. 192. (1869.) Pages quoted, 212, 213.

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the author again refers to our fossiliferous beds, saying "the Lower Brickearths of the Thames Valley . . . contain the remains of *Rhinoceros megarhinus*, which has not yet been yielded . . . by any strata of later age than the Pliocene, and are therefore brought into more intimate relation with that epoch than any other of the deposits undoubtedly Postglacial. But nevertheless the evidence afforded by the Mammoth, Tichorhine Rhinoceros, Cave-lion and Cave-hyæna is in favour of their Postglacial date. And this inference is strongly corroborated by my discovery of a skull of a Musk-sheep at Crayford. How, then, can we reconcile the clash of evidence?" He thinks that the animals could not have existed together under the same climate; that probably the part of England south of the Thames was not submerged beneath the Glacial Sea; and "that the valley of the Lower Thames roughly marks the position of the ancient Glacial coast-line in Britain, and that to the south the relics of the Preglacial continent extended without a break . . . while to the north the look-out was over a dreary expanse of sea burdened with icebergs," and that some of the southern animals "may have ventured northwards as far as the valley of the Thames." By the evidence here noted however it is 5 to 1 in favour of Post-Glacial! and we need feel less surprise at one older mammal surviving than at five newer mammals having a premature specific birth!

In 1871 PROF. PHILLIPS, speaking of an Ilford section (see p. 414), said:—"The series of these irregular layers varies from point to point, and suggests the intermitting action of violent land floods, snow melting, and drifting of shore ice, much as the gravel-beds farther up the valley;" and of the beds generally, below London, he remarked that "they evidently belong all to one geological period, and one set of variable physical conditions;"\* but he hesitates to mark their age definitely.

In 1872 MR. S. V. WOOD said "it is remarkable that in all the great sheet of the Thames gravel which preceded this Brickearth [of Grays etc.] we should get no traces of Boulders, while so many should occur in the Brick-earth itself; and the circumstance seems to me to indicate the absence of ice-action during the deposit of the former, and its commencement during the accumulation of the Brick-earths;"† but it should be remembered that the stones in question are all of greywether-sandstone and not of rocks transported from a distance.

In the same year PROF. DAWKINS again took up the subject, in a paper on "The Classification of the Pleistocene strata . . . by means of the Mammalia,‡ classing the brickearths of the Lower Thames as Middle Pleistocene, or as between the Forest-bed and most of the River Drifts, and saying "If the mammalia from these deposits be compared with the Preglacial or Pliocene on the one hand, and with the Late Pleistocene on the other, it will be seen that

\* *Geology of Oxford and the Valley of the Thames*. 8°. Oxford, pp. 470, 471.

† *Geol. Mag.*, vol. ix. p. 159.

‡ *Quart. Journ. Geol. Soc.*, vol. xxviii. p. 410. (1872.)

they are linked to the former by *Rhinoceros megarhinus*, and to the latter by *Ovibos moschatus*. The absence of the Reindeer, which was so numerous in the valley of the lower Thames [? in the gravel], and the abundant remains of the Stag, seem to me to point backwards rather than forwards in time, and to imply that the Lower Brick-earths are not of Late Pleistocene age, just as the absence of the characteristic Early Pleistocene species shows that they are not of that age." The stag being an existing British species it is not clear how its occurrence can point backward, and there is some danger in founding an argument on the absence of Reindeer from one local set of beds, which may be of the same age as others, containing remains of that animal, elsewhere.

For a discussion on the climate of the period the reader is referred to the paper itself.

The same volume contains the following remarks by GEN. PITT-RIVERS (then COL. LANE-FOX), based chiefly on the beds around Acton and Ealing:—"The presence of large tracts of brick-earth overlying the gravel, argues . . . the existence of large volumes of water at the time they were deposited. Then to what are we to attribute the strips of London Clay laid bare on the sides of the valley, and of the tributary streams, at the average level of 50 feet? Obviously to denudation. . . . Why then, is this denudation not continued along the sides of the same streams into the mid terrace and down to the present river? The mid terrace, instead of being broken into patches by denudation, like the high terrace, is continuous, following the sinuosities of the valley up to the limit of the 50-feet line, or thereabouts. I venture to suggest that . . . a body of water, occupying the whole valley up to the 50-feet line, would account for the phenomena . . . . The denudation of the patches of the high terrace would be caused by the drainage *into* this body of water. The mid-terrace gravel would be the result, in a great measure, of accumulation beneath the surface of the water."\*

In a set of papers, by PROF. J. GEIKIE, "On Changes of Climate during the Glacial Epoch," there are some general and special remarks referring to our district, as follows†:—"After carefully considering the evidence . . . there seems to me not only no proof that all these older river-gravels are of Post-glacial age, but, on the contrary, many considerations induce to the belief that such is almost a physical impossibility." In England "the further we recede from the mountains . . . the glacial drifts become less and less distinguishable. To such an extent is this the case, that geologists are sometimes at their wits' end to say whether the large stones occasionally met with in the valley-gravels have been carried into their present position by floating ice, or whether they may not have been derived from the denudation of a Boulder-clay. In the former case the stones would give

\* *Quart. Journ. Geol. Soc.*, vol. xxviii. p. 464. (1872.)

† *Geol. Mag.*, vol. ix. pp. 170, 219-221, 262. (1872.)

evidence of cold conditions; in the latter they would afford no proof of anything in particular, save river-erosion" . . .

"Again it is noteworthy that while the older river-gravels in the south of England are usually well developed, as in the basin of the Thames, those of the valleys further north occur for the most part in mere patches. This circumstance appears inexplicable on the supposition that the valley-gravels are wholly post-glacial."

In "the hilly districts of England, the interglacial deposits [with which our author classes the River Drift] must have been ploughed out again and again . . . But as we recede from the uplands . . . we get upon ground where glacial action would be less intense, and where, consequently, interglacial deposits would stand a better chance of preservation." As to the evidence of ice-action given by the "Trail" we may be allowed to doubt.

In his table of the Quaternary Deposits the river-gravels are classed as the topmost beds of the Glacial Epoch.

In his great work on "The Ancient Stone Implements of Great Britain,"\* DR. J. EVANS not only describes the Flint Implements, but also discusses at length the origin of our River Drifts and the gradual deepening of the valleys, referring largely to the Thames. He says "The presence of these beds in such a position, consisting, as they do at Highbury, of sand and brick-earth, such as can only have been deposited in comparatively tranquil water, involves the necessity either of a large lake having existed at the spot, or of its having been within access of the flood-waters of the river. But either of these conditions is impossible, unless we are to suppose that the valley of the Thames, in which London now stands [that is to say the deeper part of the valley] was at that time non-existent. It must therefore have been subsequently excavated. But again, at lower levels . . . we have gravels of a more distinctly fluvial character, and also containing Palæolithic implements. The existence, character, and position of all these beds are, therefore, perfectly in accordance with the theory of the excavation of the valley by the river, and it is extremely difficult, if not impossible, to account for them satisfactorily in any other manner"; but "it is necessary . . . that the streams, during some portion of the year at all events, should have been more torrential in character than they are at the present day . . . we must also accept as a fact that the climatal conditions were such as would enable the rivers to perform the work."

The probable conditions are discussed, and our author adds that "There is also a high probability that, at the time of the deposit of the gravels, Britain was still united to the Continent; so that, apart from other causes, there was a tendency for the climate to partake more of a continental character than at present, and to induce greater cold in winter and greater heat in summer."

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\* 8<sup>o</sup>. *Lond.* 1872. Chap. xxv. Antiquity of the River Drift. Pages quoted 600, 601, 611, 612, 616, 621, 622.

DR. EVANS then controverts MR. TYLOR's view that the valleys had their present form before the deposition in them of the River Drift (see p. 368) and that gravels at all levels on the slopes are of the same age and due to floods reaching 80 feet or more above the river-level, as follows:—"What shall we say to floods raising the levels of rivers flowing through broad valleys upwards of 80 feet, and yet having no erosive power, and the waters of which, regardless of the laws of gravity, tranquilly deposited their solid contents evenly over the slopes, or often in the greatest thickness on their higher part, and in some cases on almost isolated hills, instead of principally on the bottom?"

"The irresistible conclusion is, that owing to the wasting agency of rain, frost, and rivers, there must have been a vast change in the superficial features of the country since the time when those who fashioned the flint implements found in the high-level gravels were joint occupants of the land with the mammoth and rhinoceros, and the other departed members of the Quaternary fauna;" but with regard to any numerical representation of the time which these changes have taken, "it would seem that for the present, at least, we must judge of the antiquity of these deposits rather from the general effect produced upon our minds by the vastness of the changes that have taken place . . . since the time of their formation, than by any actual admeasurement of years or of centuries" . . .

"Taking our stand on the high terraces at Ealing, or Acton, or Highbury, and looking over the broad valley . . . with the river flowing through it at a depth of about 100 feet below its former bed, in which, beneath our feet, are relics of human art deposited at the same time as the gravels; which of us can picture to himself the lapse of time represented by the excavation of a valley on such a scale, by a river greater, perhaps, in volume than the Thames, but still draining only the same tract?"

In 1874 PROF. J. GEIKIE repeated the conclusions of his papers of 1872,\* and remarked that "the fact that the remains of northern and southern forms [of mammalia] occur commingled in our river-deposits, is only what one might have expected. . . . Rivers are constantly cutting down through their own deposits, and again filling up the excavations they make. In this way gravel and sand are banked against similar beds" of "much greater antiquity; and the line of junction it is often impossible to determine, the one deposit seeming to shade into the other."

"Palæolithic river-gravels are exclusively confined to the south and south-east of England . . . The tool-bearing drifts are . . . confined to a somewhat . . . circumscribed area."

"North of this area we find river-gravels of undoubted post-glacial age lying in the bottoms of the valleys, and occupying positions that seldom rise more than a few feet or yards above the present levels of the stream. . . . The palæolithic gravels of

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\* The Great Ice Age And its Relation to the Antiquity of Man. 8<sup>o</sup>. Lond. pp. 358, 470, 476-479, 481, with slight changes in Ed. 2, 1877.

the south, however, not only attain a great thickness, but from their position we can see that since the time of their formation very considerable derangement of the drainage-systems has taken place . . . while the palæolithic gravels of the south began to be laid down at a time when the streams were commencing to hollow out their valleys, the gravels of the north were for the most part not deposited until after the valleys in which they occur had come to assume much of their present appearance." . . .

"The south-east of England, where palæolithic and mammaliferous river-gravels and loams are so well developed, is precisely that part of the country in which we find no traces of the later glaciation, and over which the sea did not prevail during the last great submergence of the British area."

To the questions "Why are palæolithic river-gravels restricted to the south-east of England . . . What is the reason for the limitation of the southern mammalia to one small area in the south-east, and why should the mammoth and woolly rhinoceros occur so abundantly in the valley-gravels of that district, while they appear so seldom . . . in the valley-gravels of the north? The answer . . . is simply this—the palæolithic deposits are of pre-glacial and inter-glacial age, and do not, in any part, belong to post-glacial times."

In a paper on "The Glacial Period"\* MR. T. BELT said, "One of the principal effects of this great advance and accumulation of ice . . . was an interruption to the drainage of all countries whose rivers flowed northwards . . . One of the most important changes was effected in the German Ocean. Its northern half was filled with ice . . . As we know that at this time the Straits of Dover did not exist it is evident that the southern portion of the German Ocean must have been filled by a great freshwater lake . . . into which flowed all the water of the melting ice, and all the rivers that now run into the same area." . . .

"When the German Ocean was blocked up to the north by ice, a great river must have run to the south through what are now the Straits of Dover and the English Channel, receiving into one stream the waters of the Rhine, the Thames," etc. These statements however seem somewhat contradictory, involving the co-existence of a great river and of a freshwater lake at the same time and place, and supposing no Straits (which one infers to mean continuous land); but yet needing a great river, which would form a decided water-parting.

The author goes on to say "The lake occupying the area of the German Ocean must have stood much higher in spring and early summer than it did later on in the year . . . and the levels of the lower parts of the rivers running into it must have been affected by its rise and fall;" but this deals only with the lower parts of the valleys, and terraces occur also in the higher parts, which are not touched by this explanation.

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\* *Nature*, vol. x. p. 85. (1874.)

The same year DR. H. WOODWARD and MR. W. DAVIES, remarking on the differences between the modern and the old river-deposits, said "the Pleistocene Brick-earths and gravels of the Thames reveal no trace of man's presence [excepting for a flake found at Crayford], but present us with a fauna almost wholly dissimilar from that now living in Europe, and most if not all of the species of which are extinct."\* But this statement needs correction, for DR. EVANS had already noted other flint-implements from old Thames gravel, and the fauna referred to is mammalian only, the Mollusca not being of extinct species.

In a letter printed in this paper MR. WOOD reiterates his view of "the reversal of the drainage during the progress of the formation of the Thames Valley, and the denudation of the Weald."

Our authors state, with regard to the bones, that the "evidence of numbers is important as tending to prove that the heavy Bovidæ were either subjected to greater casualties, by floods or other causes, than the lighter and more fleet Cervidæ; or that they existed in greater numbers and roamed in very much larger herds. It also tends to prove that the Ruminants numerically surpassed the whole of the other Herbivores" and that "the Rhinoceros was not a common animal."

In the privately printed version the following conclusion is added:—"If we could . . . restore the physical features of the Valley of the Thames, as it existed in Pleistocene times, we should doubtless find that all those places along its lower course, where considerable deposits of Brick-earth occur, and where the remains of the larger Mammalia are found in such abundance . . . , mark the sites of ancient bays formed by the debouchment of side-valleys into the principal one, giving rise in flood times to eddies into which the floating carcasses of land-animals would indubitably be drawn, and would, in course of time, sink, and become entombed in the soft and yielding argillaceous mud beneath."

In 1875, in a general paper on "Some Valleys in the North and South of England," MR. C. E. DE RANCE accepted the view that the Valley of the Thames and its contained deposits are of Post-Glacial age, like valleys in the north that are cut through Boulder Clay.†

The same year, in a Presidential Address, DR. EVANS hesitated to accept PROF. J. GEIKIE'S view "that the Palæolithic deposits [including River Drifts] are of preglacial and interglacial age, and do not, in any part, belong to postglacial times" and concluded rather that "they are all distinctly postglacial in the sense in which that term is employed by Mr. Searles V. Wood," or in other words are newer than the Boulder Clay. This however

\* *Geol. Mag.*, dec. ii., vol. i. p. 391. Reprinted in "Catalogue of the Pleistocene Vertebrata, from the Neighbourhood of Ilford . . ." by W. DAVIES, p. xix. Privately printed. Lond. 1874.

† *Proc. Geol. Assoc.*, vol. iv., no. 4, pp. 235-243, 252.

hardly meets Prof. Geikie's contention, meaning only locally Post-Glacial.\*

The next year MR. R. W. CHEADLE and MR. B. B. WOODWARD review the question of the age of the fossiliferous brickearth of Crayford, Erith &c., chiefly from fossil-evidence; but come to no definite conclusion,† which perhaps is not to be wondered at when the stratigraphical evidence is passed by.

In 1877 PROF. HUXLEY, using the Basin of the Thames in illustration of the causes that have formed the present surface, and referring to its geological structure, said "Possibly, some of the Gravel in the Thames basin may be glacial drift, which has been disturbed and re-deposited by the river"; ‡ but he does not commit himself as to the age of the fossiliferous brickearths.

In 1879 PROF. DAWKINS restated his opinion that "the lower brick-earths of the Thames valley . . . probably belong to a period before the Glacial age"; but in this paper he makes the mistake of calling all deposits beneath the Boulder Clay "Pre-glacial," whereas in many cases such deposits are simply Glacial.§

In 1880 PROF. DAWKINS gave a resumé of his views and arguments already alluded to (p. 364),|| remarking "that the valley of the lower Thames is the only place known where the woolly and leptorhine rhinoceros are found side by side with the big-nosed species." His table of the Mammalia found in the fossiliferous brickearths seems to show how little can be argued from them. It may be thus epitomised:—

Survivals from Early Pleistocene	{ Living species 11 Extinct „ 4 }	15
New comers - - -	{ Living species 9 Extinct „ 2 }	11

Objection may be taken to the statement that relative level as a test of age of terraces is valid only on the assumption that the land has remained stationary; and the further statement that "the valley of the lower Thames was probably excavated in the Pleiocene age, and is proved by the large sheets of boulder clay and the marine shingle in Essex and Hertfordshire to have been submerged after the end of the early Pleistocene age," seems to me to be rather the reverse of the true state of the case. At all events there is no *proof*: there are no remains of Pliocene beds in the Thames Valley, nor along its borders, and the ending off of the Boulder Clay at nor near by its northern edge looks as if the valley had been partly cut through that clay. None of the valley in question being in or near Hertfordshire the Drifts of that county prove nothing concerning it.

\* *Quart. Journ. Geol. Soc.*, vol. xxxi. pp. lxxiii., lxxiv. (1875.)

† *Proc. W. Lond. Sci. Assoc.*, vol. i., pt. iii., pp. 92-98. (1876.)

‡ *Physiography: an Introduction to the Study of Nature*. 8°. *Lond.*, p. 284. There are later editions.

§ *Quart. Journ. Geol. Soc.*, vol. xxxv. p. 142.

|| *Early Man in Britain* . . . . 8°. *Lond.* Pages quoted 134, 135, 142, 143.

In a paper of the same year; which seems to have been read, or at all events to have been published, after the appearance of the work just noticed, the like statements occur,\* and it is said that "the climate at this time [that of the fossiliferous brickearths] was colder than it ever had been before in Britain, and was gradually passing into the glacial condition. It is very likely . . . that the upper strata covering the fluviatile deposits with the fossil remains are glacial, and that therefore the deposits beneath are referable to the Preglacial age." The reiteration of this unfortunate statement is strange, especially as MR. H. B. WOODWARD had shown its error.† It ought to be clearly understood that for a deposit to be Pre-glacial it must be older than the oldest division of the Glacial Drift, and not merely that it should underlie an upper member of that set of deposits. In the present case there is no evidence for even this last, the slightly disturbed-looking uppermost bed at Ilford etc. being unlike the Boulder Clay of the neighbouring heights.

PROF. DAWKINS' separation of all the rest of the River Drift, whether belonging to a higher terrace than that at Erith etc. or to a lower one, as of "Late-Pleistocene" age, whilst the fossiliferous brickearths are classed as "Mid-Pleistocene" is really answered in the paper next to be noticed, where the obvious fact that the highest terrace has been cut through by the old river, in making the hollow in which the fossiliferous brickearths were deposited, is alluded to.

MR. F. C. J. SPURRELL has drawn attention to the relation of the Crayford brickearth "to other deposits of the same river in the immediate neighbourhood." Of these he says that the oldest "is the widely spread tract of Dartford gravel [the highest terrace] extending many miles on either side of the present river Thames and bearing a definite relation on its northern as well as on its southern confines to the course of that river. It is to be found resting with remarkable regularity on [at] a level of about 98 feet above the ordnance datum line, whatever stratum it may rest on, though in pockets or pipes it occasionally descends lower. Its greatest thickness is about 35 feet. . . This gravel contains palæolithic implements . . . and it is from this gravel that I believe some of the flakes that have been found in the brickearths below have been derived."

"It appears that the river afterwards left this level and descended not less than 180 feet (perhaps more than 200), cutting a deep channel. . . . When at its lowest, the river must have been comparatively a small one. The river then began to rise slowly until the water attained, if it did not exceed, its old supremacy."

"It was during this rise that the brick-earths were deposited. . . . Then the water retreated again, washing away much of the upper layers of brick-earth, and giving much of the present

\* *Quart. Journ. Geol. Soc.*, vol. xxxvi. pp. 897, 898. (1880.)

† *Geol. Mag.*, dec. ii., vol. vi. p. 235. (1879.)



form and slope to the lower part of the valley. At its close came down rushes of gravel, chiefly from the highest bed, crushing into the softer layer beneath, and making festoons and loops when seen in section: this is known by the name of "trail," and accumulated lower down in large banks."\*

MR. WOOD however calls the high terrace of gravel above alluded to "Marine sand and Gravel of the Thames Valley,"† though, as no marine remains have been found in it, one can see no reason for this.

In 1881 PROF. J. GEIKIE, after accepting PROF. PRESTWICH's explanation of our river-terraces, etc.,‡ said "Although it is common to speak of high-level and low-level terraces, the one series really passes down into the other. Neither do these terraces occur continuously along the valley-slopes . . . it is often hard . . . to distinguish anything like a terrace. . . . Again . . . so long a time must have elapsed between the formation of the upper or oldest and lower or youngest valley-gravels, that the former . . . would be subjected to the slow but continuous . . . action of atmospheric agents of waste."

"The evidence supplied by the old "river-drifts" . . . speaks to us of alternations of mild or genial and cold climatic conditions."

"No one who shall examine any well-developed river-deposits of Pleistocene age, such as those of the Thames . . . can fail to see that they all form part of one and the same series. They point to the long-continued action of erosion and deposition, and doubtless the river that transported the sediments, and spread them out . . . behaved in precisely the same manner as any other river at the present day."

Holding that our southern River Drifts are only Post-glacial in the sense of being newer than our great southern sheet of Boulder Clay, and are really synchronous with newer Glacial deposits to the north, our author thinks "that we are driven to conclude that the Palæolithic Age came to a close with the last glacial epoch."

The next year MR. WOOD again referred to the "Dartford [or high terrace] gravel," as of Glacial age, and said that it "has no more connection with the Thames than it has with the Severn . . . for it accumulated beneath the sea when the valleys of both, and probably the lowest of the partings between them also, were submerged;" but this view is purely theoretical, and not supported by the occurrence of the flint implements noted by MR. SPURRELL (above). I cannot understand how this gravel is traced northward up the valley of the Lea, until, north of our district "it passes both under and over the Chalky [Boulder] Clay;" for it seems to me that at least two gravels have been here confused, the comparatively low flat of the Lea gravel, bordering

\* *Quart. Journ. Geol. Soc.*, vol. xxxvi. pp. 546-548. (1880.)

† *Ibid.*, plate xxi., fig. vi.

‡ *Prehistoric Europe a Geological Sketch.* 8°. Lond. Pages quoted, 182, 185-187, 362.

the river, being taken to represent the high terrace of the Thames.\* The system of processes invoked by MR. WOOD, both as regards this gravel and the later "Cyrena-formation," as he calls the brickearths etc. yielding *Corbicula fluminalis*, is so involved that I must refer the reader to his paper (pp. 675-678, 692-696, 702-704, 709-712, 727-729, 741, plate xxvi.).

The same year, in noticing the shells, found by MR. WORTHINGTON SMITH at Clapton Railway Station, DR. J. GWYN JEFFREYS said "The occurrence of *Pisidium fontinale*, var. *Henslowana*, as well as the *tout ensemble* of all these fossil shells, induces me to believe that they had been thrown up by floods on the banks of a large river such as the Thames."†

The valley of the Thames is referred to in the remarkable set of papers which MR. H. H. HOWORTH began in 1882,‡ and which, I presume, formed the basis of his book, "The Mammoth and the Flood" (1887). Speaking of the vertical stones in the top bed, the so-called Trail, at Ilford, he said, "Surely . . . the probability is that these unweathered stones have largely arisen *in situ* from the filtration of water charged with carbonate of lime which would naturally deposit concretions exactly in this way, the long axes being in the direction of the flow of filtering water." As the stones in question are not calcareous, as moreover when concretionary calcareous stones occur in clays or loams they have the longer axis along the planes of bedding, and as infiltrating water is in the habit of dissolving out carbonate of lime from a top bed, rather than of depositing it, there is not much to be said of the above "probability." Since this author accounts for anything and everything (whether river-brickearth or plateau-loam, gravel-terraces or marine drift) by one and the same cause, and can see no explanation but a "great post-glacial flood," we may fairly pass on.

In 1883 PROF. DAWKINS again repeated his views as to the greater age of the fossiliferous brickearth, and said "the relation of this deposit to the Boulder-clays further north seems to me to be defined by the fact that it underlies the confused strata known under the name of "Trail," in which the action of either ice or snow is obvious in the transport of angular masses of soft Woolwich Clays at Erith . . . The Lower Brick-earths, too, differ from the other fluvial deposits in the Thames valley in the fact that they contain no erratics, and therefore must have been formed before the erratics were brought into the area of the Thames-valley by the ice, and before the streams had begun to attack the Boulder-clays, and to deposit their débris in the gravel bands of the Thames valley. From these two considerations I am inclined to hold that these deposits are preglacial, in the sense of being before the period of the Boulder-clay in the Thames valley."§

\* *Quart. Journ. Geol. Soc.*, vol. xxxviii. pp. 676, 677. (1882.)

† *Nature*, vol. xxvi. p. 581. (1882.)

‡ *Geol. Mag.*, dec. ii., vol. ix., vol. x. (1883.)

§ *Quart. Journ. Geol. Soc.*, vol. xxxix. pp. 578, 579.

This quotation seems to me to show some misconceptions. Thus too much is made of the Trail, a mere thin surface-deposit that occurs very generally, and the presence of which, if it is to prove Glacial origin (which is very doubtful) will result in a wash of such colour as may be chosen for Glacial Drift being spread rather widely over our Maps. Again the large masses of Woolwich Beds etc. found over the brickearth at Erith (see p. 435) have nothing to do with this Trail, as far as I can see; but may be due to land-slip. Thirdly the absence of erratics proves nothing: they are far from common in our River Drifts, and are hardly to be looked for in such deposits as loam, which are not exactly of torrential origin. Lastly there is no Boulder Clay in the Thames Valley, unless the Trail is assumed to represent it, and that is pure assumption. It is satisfactory however to find our author explaining his use of the term Pre-Glacial, and thereby saving some misunderstanding.

In 1883 we have, I believe, PROF. DAWKINS' last note as to the fossiliferous brickearths of the Lower Thames, in which he frankly confesses inability "to form an opinion about their relation to the submergence . . . under the waves of the glacial sea," adding "They are quite as likely to be pre- as post-glacial."\*

In the same year MR. J. E. GREENHILL seems to have come to the conclusion that our River Drifts are Preglacial, as he says "paleolithic man was doubtless compelled to flee as the mighty glaciers claimed from him his territory. Unwilling to yield, he retraced his steps as soon as more favourable circumstances set in, and re-occupied the ground as the once advancing ice began its retreat, and the elevation of the land was succeeded by a depression . . . so great that the deep valleys were submerged and covered by the waters."† As the returning man is our neolithic ancestor one can hardly accept the submergence, there being no trace of the sea in our valleys, except in their estuaries.

In 1885 MR. J. G. GOODCHILD published a paper on "Some Superficial Deposits of North Kent," in which he treated of the Valley Drifts,‡ saying that "the loams occasionally give place to beds of a more sandy or of a more clayey nature . . . but, as a rule . . . the more arenaceous parts of the deposits prevail nearer the bottom . . . while the upper part tends more or less to assume an argillaceous character . . . The gravels occur on all horizons throughout the loams, but there is generally more or less gravel at the bottom . . . and more commonly still there is a second bed at the top. The bottom gravel and the top come together in some localities where the brick-earths have thinned out, and they thus occupy a wider area than do the brick-earths."

He also said "I see no reason to believe that more denudation has taken place in the Thames valley in Post-glacial times than

\* Address to the Department of Anthropology. *Rep. Brit. Assoc. for 1882*, p. 601.

† Prehistoric Hackney. (Paper ii.) *Neolithic Age*. 8°. London, 1883.

‡ *Proc. Geol. Assoc.*, vol. ix., no. 3, pp. 151-159.

has taken place in the corresponding times in the north of England;" but this depends on the sense in which "Post-Glacial" is used. If our southern Post-Glacial time (using the term strictly locally) was far longer than that in the north, where glacial conditions lasted longer, the comparison cannot be made.

Our author continues "we are asked to believe that the Thames has lowered the shores of North Kent between three hundred and four hundred feet since the highest-lying brick-earths and gravels were first formed"; but the age of those high-lying beds is as yet an unsolved problem! "At the known rate of denudation now taking place, assuming that rate to have been always the same, it would require nearly a million years to accomplish that result"; but who makes the assumption in question? Surely the river that formed the great sheets of gravel must have been far more powerful than the present stream!

As to a difficulty raised from the remains of the older mammalia occurring at the lower level and the newer ones at a higher level, it should be noted that the higher level gravels have yielded few such remains, and that the large yields have come *only* from the fossiliferous brickearths of the Lower Thames. The comparison therefore can hardly be made. However as the author further on expresses the view that "the stratigraphical value of nearly all the evidence afforded by the mammalian remains in the deposits of the Thames Valley is about equal to that afforded by the Belemnites . . . from the Boulder Clays of Finchley" [= nothing], he fully meets his own objection.

Nor can one quite see "how much simpler is the explanation . . . put forward . . . by the late Mr. Belt [see above] . . . an arm of the Continental ice that reached our shores from Scandinavia at the climax of the glacial period—after the Thames valley had been shaped into nearly its present form [what by?] . . . as a dam across the mouths of the rivers . . . This would pond back the waters of such rivers as the Thames"; but it would hardly help in the preservation of great numbers of delicate shells, some of southern kinds; nor does it explain the mammalian difficulty.

In 1886 MR. J. A. BROWN, in describing "The Thames-valley Surface-deposits of the Ealing District,"\* said "that the high bench-deposits reach far above the 100-foot level," or above the level which many years before, I had taken as their local limit. MR. BROWN does me the justice to say "this fact is, however, one which Mr. Whitaker is evidently prepared for." Certainly my work in mapping Drifts has led me to feel little surprise at anything that turns up with regard to these deposits; just as my reading of what has been written on the subject, as may be judged from what has gone before, has prepared me to hear, without astonishment, the most varied theories about the River Drifts.

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\* *Quart. Journ. Geol. Soc.*, vol. xlii. pp. 192-199.

Our author, who is one of those useful local observers before referred to, as having extended our knowledge of these deposits, says that "the high-level gravels proper in the neighbourhood of Ealing flank the sides and, in some cases, reach nearly to the top of the hills which form the inner-valley ridge," the highest ground of which is at the Mount, etc. where the older beds, alluded to at p. 308, were found by MR. BROWN. At Castlebar Hill he found gravels, higher than those shown on the Geological Survey Map, and "similar gravels occur on the north slope of the hill, and hence appear to be out of the range of what have hitherto been regarded as bench-gravels," which description of beds commences here "on the flanks of the hills at 130 feet, and is bounded northwards and upwards by London Clay, or stiff brick-earth much resembling it. This clay-covered area . . . contains pot-holes or depressions filled with gravel, which . . . indicate the former continuity of the higher and lower gravels." . . .

"From the foregoing evidence I am induced to believe that these lower gravels were connected, until denudation severed them, with the more beach-like deposits on the top of Castlebar Hill, if not also with the "furrow" or Glacial gravels, &c. on "the Mount," and that all are essentially parts of but one series of deposits. The pebbly gravels at 155 to 160 feet above O. D. . . would appear to have been accumulated when the physical geography of the country was altogether different from what it is now. It would seem as if the northern tributaries could not have been then eroded; that very little, if any, of the present conformation of the Thames Valley had been fashioned" . . .

"The next series of beds in chronological succession present us not only with man's handiwork, but with evidence that he lived in the Thames Valley at successive levels up to the period when the brick-earth series of loams, sands, and trail covered up and preserved the works of Palæolithic man."

The gravel at Alperton, etc. which MR. BROWN takes to belong to a high terrace of the Thames, seems to belong to the tributary valley of the Brent, but our author thinks that "lagoons (still retaining a connexion with the main channel of the stream [the Thames]) extended over much of the low-lying country to the north, and were separated one from another by large tracts of low-lying swampy country," presumably rather than that there was a tributary stream, then as now.

He notes that "the waste and slipping of the surface of the London-Clay hills in this district . . . even under the present temperate condition of things, is so marked, that it must have been a very important factor" in former times.

This same year MR. F. C. J. SPURRELL treated of the "History of the Rivers and Denudation of West Kent," and some remarks may be taken from this paper.\*

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\* *Rep. W. Kent Nat. Hist. Soc.* 1896.

The gravels of the Norwood hills are referred to as the highest of the old Wandle; but it seems possible that, if these are River Gravels, they may belong rather to the old Thames.

"The gravel spread of Dartford Heath, Greenhithe, and Swanscombe, contains many rolled shells of *Gryphæa* [derived Jurassic fossils] . . . There is therefore, just a possibility that the [Boulder] clay lay in Kent." . . .

"All the gravels of the Thames proper [below London] are distinguished by a composition differing from those at a level exceeding 200 feet, in as much as they contain, in varying proportions according to locality, erratics or the pebbles and fossils of Northern origin, which have been washed from the Glacial gravels and clays which still line the Northern brow of its valley, and which may have occupied a small part of what is now within its present well marked area of denudation." These two paragraphs seem to me fairly conclusive as to the valley having been worn out since the deposition of the Boulder Clay, for it is hardly possible that the fossils in question could get into the River Gravel from any other source than the Glacial Drift. "On the South, however, where the supply of materials from the chalk hills, and the Weald, by tributaries which do not pass through glacial beds, is very abundant, we find the erratics diminish in proportion." . . .

"The very high patches of Kingston and Wimbledon have not yet been found to contain any mammalian remains or flint implements. But the high level gravels of Dartford do, as also do the high level gravels of Middlesex and Essex, yet though the unfossiliferous condition of the high level gravels West of Shooters Hill may be thought to separate them from those of Middlesex, Essex, and the east, they do not appear to differ more than some parts differ from other parts of those spreads known to be fossiliferous, so that I class all these as one," and very rightly. "The material of the higher level gravels differs but slightly from that of the lower; the main difference being diminution . . . in the lower terraces, of the proportions of foreign pebbles."

"Although the gravels of the higher terrace do not show much evidence of glaciation during their deposition, yet I have seen at their base on Dartford Heath and elsewhere, detached masses of London clay of considerable size which could only, I think, have been carried by ice." . . .

"On the North side . . . the high level gravels have passed by gentle gradations, in some places without a break, down to the lower terrace, although occasionally a denuded space separates them." This is "the consequence of the gentle abandonment of the Northern part of the river bed for the Southern."

I cannot follow our author however when he says that "the old Wandle . . . continued Eastward, from Croydon to Deptford," nor in the statement that "all the rivers of the district, running North and South, have tended to widen their channels Eastward;" for though this is certainly the case with

the chief tributary-stream, the Lea, there is no sign of it in the other tributaries, and the present Wandle flows mostly along the western foot of its valley.

When MR. SPURRELL says, of a later period in the formation of the River Drift, that there probably was a "depression of the land until the sea advanced far up the old river valley, raising its flood-waters to a great height," I think we have a right to ask for some evidence of the marine occupation of the valley, other than the theoretical one that he offers. No marine remains have been found anywhere, in brickearths or in gravels.

Part ii. of this paper is thus begun:—"It is not only to rivers, however, that so much and apparently such rapid denudation has to be credited. It is largely to snow and ice . . . I do not use the phrase "the glacial epoch," because any term implying a sharply defined time in which this district was ice-bound is inapplicable to the subject. Since the day the crests of our hills emerged from a sea covered with bergs, ice and snow have apparently held this county [Kent] to the exclusion of a truly genial climate, and although it is not strictly glacial now, the improvement appears as if commencing but yesterday, compared with the long ages of cold preceding."

The author then (pp. 28-51 and plates i., ii., of separate copies) treats in some detail of the Trail, or "material filling troughs and hollows," and of other surface-phenomena, regarded as due to the "movement of ice or thawing soil," to "the re-arrangement of detached and comminuted rocks after the thawing of the ice," and to rain-wash; subjects which time forbids one to enter on now. Anyone interested in this line of research should study this paper, and should of course consult also the REV. O. FISHER's paper,\* which however refers to places outside our district. With this subject MR. SPURRELL discusses the question of the formation of dry chalk-valleys, which was also treated of by MR. C. REID in the following year,† with reference to a more southern tract.

MR. J. A. BROWN has embodied the substance of his various papers in a book.‡ Speaking of the high terrace and of the earliest men, he says "In the lowest beds we have evidence of torrential currents in the deposition of the large stone gravel with masses of flint, very slightly rolled, from which they fabricated their implements. Later apparently less active conditions prevailed; and the brickearths tell us more in the same direction;" but the unrolled character of the flints seems to point rather to ice-carriage than to torrents. "The repeated action of the waters of the much wider river of that time, at one period covering old land surfaces, and others forming them as banks and islands . . . would in time involve vast changes, with all of which man appears to have been associated."

\* *Quart. Journ. Geol. Soc.*, vol. xxii. pp. 553-565. (1866.)

† *Ibid.*, vol. xliii. pp. 364-373. (1887.)

‡ *Palæolithic Man in N.W. Middlesex* . . 8°. Lond. Pages referred to 63-65, 68.

In thinking that the mid terrace beds owe their lower level partly to "the slightly more rapid rate at which the country rose at that time," it is questionable whether the author is not on the wrong tack. The smaller river was more likely to have resulted from depression, as elevation would increase the rainfall. In this mid terrace "the coarse ballast found always at the base of the high terrace deposits is replaced by sand containing delicate shells unbroken and bones of the larger mammalia. Few flint-implements and flakes have hitherto been found."

In the statement of the possibility "that Palæolithic man beheld the land now under the 300 foot contour in Middlesex as an arm of the sea or sea loch," it seems to have been forgotten that the land *now* under that contour was not so *then*: great denudation has taken place, throwing back the contour-lines; and of the presence of the sea, at that time, in Middlesex there is no evidence.

The last paper to be noticed is from the pen of our veteran observer in this field, as in many others, PROF. PRESTWICH,\* in which he said:—"Measured by our own limited experience, the excavation of the Postglacial valleys, the life of the successive generations of the Pleistocene Mammalia and the dying-out . . . of a large number of species might seem to demand a long period of time . . . It was felt, however, on the other hand, that the very large proportion of existing species of Vertebrata and Invertebrata which came in with the Pleistocene period and had since undergone no change . . . combined with the stationary condition of Man himself during so long an interval, presented serious objections to adopting such lengthened periods" as had been suggested.

He then noted a change of opinion, to the effect "that the high-level beds . . . of the Thames at the Reculvers [= the high terrace] . . . date back to Glacial or Preglacial times, not in the sense of being anterior to the Glacial epoch, but in the sense of belonging to that part of the Glacial epoch when the great ice-sheet was advancing, but had not yet invaded the whole of this area." It may be asked however what evidence is there that it ever did invade the area in question? Though no reference is made to our district, I take it that the above conclusion may be applied to it, and, in the sense that some of our River Drift may be equal in age to Glacial Drift elsewhere, it may be accepted as a fitting correction to the earlier view of the absolute Post-Glacial age of the River Drift.

Into the question of the numerical value, in years, either of the Glacial or of the Post-Glacial epoch it seems to me unsafe to enter: We are far from having sufficient data to work with, and whilst our author is disposed to allow Man "no greater antiquity than perhaps about 20,000 to 30,000 years," others ask for much more.

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\* *Quart. Journ. Geol. Soc.*, vol. xliii. pp. 393, 407. (1887.)



*General Conclusions.*

Having now critically examined the works that deal with the questions of the age and of the origin of our River Drift, it may be well to state the conclusions to which I have been led, not only from a careful study of the tolerably extensive literature of the subject, but also by long-continued work in the field, work which has given me an intimate personal knowledge of the greater part of the district, and a fair acquaintance with the rest.

The reasons for these conclusions have already been given, for the most part at least, in the foregoing pages; so that the conclusions themselves may now be given somewhat tersely, but without any attempt at dogmatism, there being many points needing further consideration and some difficulties to overcome.

1. That the gravels and brickearths of the valley of the Thames were deposited by an old river, flowing in the same general direction as the present one, and that these beds therefore may well be called River Drift.

2. That the old river must have been larger and of a more torrential character than the present one, the former being shown by the far wider tract within which it flowed, and the latter by the much coarser character of most of its deposits.

3. That this increase in size and in power must have been owing, for the most part, to greater height of the land, causing greater condensation of atmospheric moisture, and greater fall of rain or snow. There may too have been a steeper slope of the river-bed, which would give more power of transport.

4. That such rise of the land would make our island part of Europe, and would give it a more continental climate, with colder winter. This would bring on semi-glacial conditions, at all events at times.

5. That the successive terraces of River Drift were formed in due order, from the highest to the lowest, there having been alternate periods of erosion and of deposition (more or less); so that, after the deposition of the highest terrace of Drift, the valley was deepened, and in the then narrower channel another terrace of Drift was deposited, to be in its turn cut through, by further deepening and narrowing of the channel.

6. That this process may point to a general lessening of the size of the river, as time went on, to a general lowering of the land, and to a general toning down of the rigour of the climate. But there is much yet to be learnt as to this.

7. That the stratigraphical evidence, from the position of the River Drifts, is conclusive as to their age (relatively to other beds in the neighbourhood), and that it cannot be contravened by slight difficulties as to their fossils: difficulties which are likely to be swept away by further knowledge.

8. That the cutting out of the valley (to the chief extent at least), and the formation of its contained Drifts, is *locally* Post-

Glacial, that is to say is later than the Boulder Clay, which, in Essex, comes up to the northern crest of the valley.

9. That nevertheless the Thames River Drifts may be as old as, or even older than, certain beds of Glacial Drift, which occur only further north, where glacial conditions lasted longer.

10. That man may have lived in the Thames Valley whilst northern England was under Glacial conditions and uninhabitable; and that River Drift, with flint-implements, may have been formed in the south, whilst strictly glacial deposits were being formed in the north.

11. That the terms Pre-Glacial, Glacial, Inter-Glacial, and Post-Glacial are liable to mislead, being given in some cases to equivalent beds, and that they are not fairly applicable for general use, but only locally. It seems to me that for all beds between the Pliocene and the Recent deposits (Alluvium, etc.) the general term Drift is enough, and that such divisional terms as Glacial Drift, River Drift, and Marine Drift might be used simply to express the conditions of deposit, without reference to relative age.

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The great mistake made in the consideration of our River Drift, with regard to classification and to age, seems to have been the too definite use of the term Post-Glacial, as representing a period wholly later, everywhere, than the Glacial Drift. This mistake was unavoidable with the knowledge at first possessed, and no blame therefore is attachable to those who held to it.

The time however seems now to have come when it should be put an end to, and when geologists should acknowledge that further work has shown that the Great Ice Age was a period of varying extent in various districts, not one sharply marked off from all other geologic time.

The acceptance of this truth, as one may venture to call it, should put an end to further dispute as to whether Man is Glacial or Post-Glacial, in regard to the time of his first appearance. He may be both, without any contradiction! Glacial (or Inter-Glacial, if that term be preferred) to the north, where the icy conditions began earlier and lasted longer, but were subject to local or temporary improvements: Post-Glacial to the south, as in the Valley of the Thames, where the later stages of glaciation never came, or were so mildly represented that they did not drive away our race, albeit our River Drifts show signs of rigorous climate. Pre-Glacial is too indefinite a term for useful application, and the question whether Man existed before the period of the Drift is one that is yet unanswered and that does not concern us here.

## CHAPTER 22. RIVER DRIFT.

VALLEY OF THE THAMES, BERKSHIRE, BUCKINGHAMSHIRE,  
AND MIDDLESEX.

In describing the Drift along our main valley it will be convenient to divide the district into blocks, bounded by the tributaries, and to follow the course of the river, from west to east. Except at first, where the valley is narrow and the Drift of comparatively small area, these blocks will also be bounded by the Thames itself.

*Above the Loudwater.*

In this tract there is mostly but one terrace of gravel in the valley-bottom, remains of a high terrace being rare, unless some of the patches, north of the river near Hurley, that have been coloured as Glacial gravel, should turn out to belong to this series. Even the higher mass west of the Loddon seems to slope down to that stream.

In this higher mass the gravel has been proved by wells at Woodley Green, and it is shown in the railway-cutting to the north.

On the western side of the Thames, from Shiplake to Medmenham, the gravel rises gently from the river-flat, its boundary for the most part following the contour of the ground, and being nowhere a mile from the river (partly in Sheet 13). The only noteworthy section was on the western side of Oaken Grove, W.S.W. of Hambledon, in a pit that showed from 15 to 18 feet of coarse gravel (many very large flints, and pebbles of quartz, quartz-rock, and flint) with enough chalk in it to give it a whitish colour, and here and there to cement masses together: the matrix indeed looked very like a coarse mortar.

Going back to the Berkshire side of the Thames, there is a small low strip of gravel at the foot of the high chalk cliff opposite Henley (in Sheet 13). From Remenham to Aston there is more; and whilst the Chalk is at the surface on the southern side of the lane, just above, gravel again comes on in the form of two outliers, the remains of a higher terrace, the rest of which has been denuded. There was a gravel-pit by the road east of the church, and a chalk-pit just below. Another and larger mass spreads from the river at Culham Court to the cliff-foot at Bisham, its boundary-line gradually rising to a higher level at Hurley Bottom, and then falling eastward. On the northern side of the high road at the foot of Rose Hill there was a pit, more than eight feet deep, in gravel made up of flints, flint-pebbles, and pieces of chalk, the last in great abundance; and a like chalk-gravel occurs about the oval plantation in the park at Culham Court. On the other side of the road, just west of the Hurley turnpike, a gravel-pit gave a very good and somewhat remarkable section. When I saw it (in August 1860) the greater part was hidden by turf and fallen earth, the eastern end being the clearest and showing the following beds:—

Shattered flints (mostly large) and small pieces of chalk, in a sandy matrix; lenticular masses of light-brown sand at one part; 5 to 6 feet.

Buff sand, partly clayey; 6 to 7 feet.

Sandy gravel; of subangular flints, pebbles of flint, of quartz and of quartz-rock, and pieces of chalk; not gone through; 7 feet.

In the last bed I found a piece of a large *Ostrea* or *Gryphæa* (Oolitic), the only fossil from older beds, excepting those in chalk-flints, that I have found in the Valley Drifts of this district. At the western end of the pit this bed was rather thinner, and buff sand was shown below it, and at another part there was at the top of the section an earth made of little else than small pieces of chalk. In the chalky gravel that here forms the top bed, as also in that at

Rose Hill, there are pipes of a brown clayey earth with flints, most likely a mere soil, owing to atmospheric action.

From the sections noticed above it is clear that the gravel between Henley and Marlow is in great part made up from the chalk itself, and not only from the hard flints in that rock, and that this is the case not with the lower part only, but also with the higher.

The Hurley Pit has yielded many fine Mammalian remains, which were saved through the care of Mr. Sheldon Wilkinson, of Great Marlow, but were dispersed after his death, in 1863. He told me that all of them were found in the gravel at a depth of about 18 feet from the surface, and that they included bones, horns and teeth belonging to ox, reindeer, elephant, hippopotamus, rhinoceros, horse, etc.

Again crossing the Thames, we find gravel spreading northward from the river from Hurleyford Grove, by the north of Great and Little Marlow, to the Loudwater Valley. It may perhaps run further up the valley N.W. of Great Marlow than is shown on the map. From this eastward to beyond Little Marlow its boundary-line is at a comparatively high level, some way up the flanks of the hills. There were several pits, and Mr. H. B. WOODWARD notes that some of these showed "about 12 feet of sandy gravel, the bottom not then reached; pebbles of grit were seen," and he adds that "the gravel is often hidden by a loamy soil." Of the small high patch north of Cours End he says that "it is probably River Gravel, but might be merely a wash from the still higher gravel on the hill-top."

On the southern side of the Thames between Great Marlow and Maidenhead there is brick-earth along the valley that runs from Park Corner by Cookham Dean Common to Cookham Dean. At the first place there were pits showing in parts 10 or 12 feet of brown loam, with thin layers of flint-pebbles and sub-angular flints. I am not sure whether this deposit belongs to the River Drift, or whether it is a mere wash from the Tertiary beds of the higher ground.

On the top of the steep chalk-cliff on the southern side of the Thames, at Winter Hill Farm, there is gravel, the remains most likely of a very high terrace of River Drift.

#### *Islands of Gravel.*

Besides the tracts above described, over which the gravel is at the surface, it must be remembered that beneath the alluvium of the river it is also present. Moreover, it is not uncommon to find masses of gravel cropping out from beneath, and surrounded on all sides by, the alluvium of the river. These may be called "islands." There is a small one about three quarters of a mile south of Shiplake, and another in Wargrave Marsh. Others occur on the west of Hambleton Lock, at Medmenham Abbey, at Low Grounds (S.W. of Great Marlow), and just east of Marlow Mills.

#### *Right Side from Cookham to Egham.*

On the Berkshire side, between Cook Marsh and the Great Western Railway near Maidenhead, is a most interesting gravel-district; for although of no great breadth, compared to the wide spreading mass further east, yet as the gravel is here underlain by the Chalk, and not, as there, by the softer Tertiary beds, the side-valleys worn through it are clearer than is the case to the east; moreover the main facts are here brought together into a small space, not scattered over a large one. To make the following remarks more easily understood, a map of the country between Cookham and Maidenhead is given in figure 67. It is from a tracing of my working-copy, and therefore on the same scale as the Geological Survey Map; but whereas in the latter the gravel is all mapped as one mass, in this woodcut each terrace is shown. It will be seen that the upper boundary of the gravel is very irregular and winding: this is owing not to the original deposition of the gravel, but to erosion through it to the Chalk beneath; for here the gravel does not fill the bottoms of the smaller hollows

or side-valleys, but on the contrary forms their sides, whilst the Chalk is found in their lowest parts. It will also be seen that these creeks, so to speak, of Chalk do not reach beyond the highest terrace, but are brought to an end at the higher edge of the second terrace, by the gravel there falling to a lower level (see fig. 70). In some places the erosion of the gravel of the highest terrace has left outliers, surrounded on all sides by the Chalk; and it is not unlikely indeed that the whole of that terrace may be cut off in this manner, by a very thin strip of Chalk coming to the surface along the boundary of the second terrace; but as loose matter like gravel is often brought down by rain to a lower level, so as to hide its original boundary, this is doubtful, although it is certain that the Chalk is very near the surface along that line. Since this woodcut was made a little more gravel has been mapped on the north, but this is immaterial.

Along the railway-cutting through the most northern outlier in fig. 69 the gravel is well shown, and is cut through to the Chalk, except at the southern part; there were pits just west of Cookham railway-station; brown sandy gravel with beds of sand is shown in the road-cutting half a mile to the south, and thence to Maidenhead there were many other sections. At and west of the station on the branch-line at that town the gravel is again shown (see p. 183); whilst a little to the east there is a large chalk-pit, without any gravel-capping; and still further a brickyard, giving a section, many feet in depth, of brown sandy brick-earth, which belongs to the second terrace, and must abut rather sharply against the Chalk. The lowest terrace rises but slightly above the alluvium, forming a flat only a few feet higher than that of the latter. This terrace moreover seems not to be continuous, but to have been worn away by the river in such manner that the alluvium sometimes abuts against the second terrace, in which case the gravel generally rises at once well above the marsh-land. However it is not always easy to make out to what terrace a gravel-flat may belong.

At Cookham, at Taplow Mills, and at the long flat of the lowest terrace from Whitbrook Common (south of Cookham) to Maidenhead there are islands.

The section fig. 70, part of the line of which is shown on the map, fig. 69, may help to give an idea of the different terraces. It is carried westwards through the Tertiary outlier near Cookham Dean. It must be borne in mind that the horizontal scale of the section is twice, and the vertical scale therefore six times, as large as that of the map: even with this some exaggeration could not be helped.

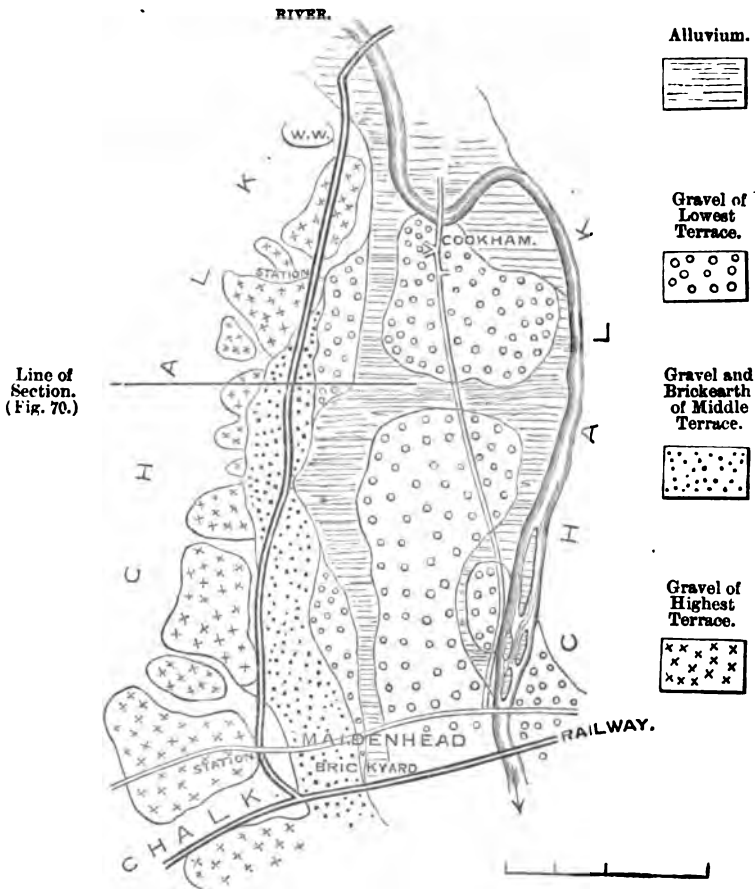
The third terrace ends off on the west somewhat suddenly, rising very slightly above the Chalk, which shows that the gravel has spread further in that direction, its present boundary being caused by denudation.

In the higher terrace (only partly shown in fig. 69) spreading from the railway S.W. of Maidenhead to Shoppenhanger's Farm and to the west of Bray Wick, there were many sections. Thence eastward to Windsor the boundary-line is somewhat doubtful, as the Tertiary beds for the most part do not rise at once from beneath the gravel, but for some distance form a flat continuous with it. Near the main road, however, there were many gravel-pits. The sides of the brook half a mile west of Surly Hall show two or three feet of clay over the gravel; this may be merely the wash of the Tertiary-land on the south, but if there be much of it the boundary-line of the gravel will be all the more doubtful.

I was told, by the gardener, that the well at St. Andrew's Hospital Clewer, passed through the following beds, and that three other wells gave much the same section:

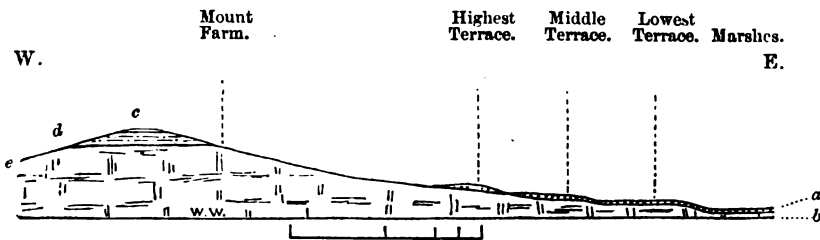
			FEET.
[Valley Drift.]	Loam	- about	4
	Stiffer loam	- "	2
	Sand	- "	3
	Gravel	- "	2 or 3
Blue [London] Clay.			

**Fig. 69.—Map of the Terraces of Gravel N. of Maidenhead.**  
N.



Scale : an inch to a mile.

**Fig. 70.—Section from the Marsh S. of Cookham to the Hill S. of Cookham Dean.**



Horizontal Scale, 2 inches to a mile. Vertical Scale, about three times as great (an inch to 880 feet). \* Sea-level (approximate).

a Alluvium. b Gravel. c London Clay. d Reading Beds. e Chalk.

The woodcutter has failed to show the alluvium above the gravel on the extreme E. of the section.

The excavations for the foundations of the new Infantry Barracks at Windsor showed a considerable thickness of gravel, and I saw, in 1867, in rear of the old Barracks and in front of the new Sergeant's Quarters, a pit 17 feet deep, in rather fine sandy gravel, with many Mammalian bones, of which a large collection was made by CAPT. LUARD, R.E., who told me that nearly all came from depths below 9 feet from the ground.

PROF. W. B. DAWKINS has described this find as evidence of a "Reindeer-ford," saying: "on visiting the spot . . . I found that more than half of the remains belonged to the reindeer, the rest to bisons, horses, wolves, and bears. They had evidently been swept down by the current from some point higher up the stream . . . We may infer that a Palæolithic hunter, standing on one of the hills commanding a view of the district above Windsor in the winter time, would have seen vast herds of reindeer crossing the stream, and in the summer herds of horses and bisons availing themselves of the same fords, with wolves and bears in their train."\*

Along Alexandra Terrace, south of the Barracks, I saw, in 1869, sections in brown sandy clay, loam, gravel, and sand; London Clay being touched at the eastern end.

From Windsor to Egham the gravel does not seem to rise to any great height above the river, and along the edge of the alluvial flat of Long Mead and Runney Mead there is but a narrow fringe of it. At the lodge by the Victoria Bridge in the Home Park I saw, in February 1858, a little gravel over five or six feet of light-coloured sand. Remains of elephant, ox, and deer have been found "near the new garden at Frogmore, in a gravel-pit. . . at about the depth of 15 feet from the surface. The upper soil for about four or five feet is sandy loam, then there is six or seven feet of red gravel, and three or four feet of washed gravel (wet gravel?) in which the bones were found."†

#### *Northern Side from Maidenhead to the Colne.*

On the northern side of the Thames east of Maidenhead the gravel and brick-earth take up a very great space, the boundary-line running thence eastward to the northern part of London. This large tract may be divided into four divisions, by the Colne, the Brent, and the Serpentine.

The boundary-line winds round the hill on which Taplow stands, getting higher and higher in its north-easterly course to Poyle and Burnham Grove, from which last place, by the north of Farnham Royal, Stoke Poges, and Wexham, to Iver, on the Colne, it is doubtful. This gravel is here but slightly separated from that of the higher levels of Dropmore, Stoke, and Fulmer Commons, &c. (see pp. 302, 303) by a narrow outcrop of the Tertiary beds; indeed there may be some doubt as to whether the high-level gravel here is not merely a higher terrace of the lower deposit. There are two outlying patches at Taplow and to the north that must belong to the latter.

East of Burnham the gravel is cut through by the valley along which a small stream flows to Ash Mill, and it is not unlikely that further east other brook-valleys may cut through the gravel to the Tertiary beds; some must nearly do so at all events.

There are many signs of terraces, but they are not very well marked. One seems to run by the south of Farnham and Stoke churches, and by the north of Wexham church to the southern end of Langley Park; and another at a lower level, nearly along the high road from Taplow railway-station to Ash Mill, and then on the south of that road to Upton.

On the northern side of the railway, a little east of this station, there is a very large pit, in part of which the gravel is cut through to the chalk. It was here that the REV. C. KINGSLEY and SIR J. LUBBOCK found the skull of the musk-sheep (*Ovis moschatus*) described by SIR R. OWEN.‡ In his "Note on the Gravel, &c." PROF. PRESTWICH says that besides this skull "Mr. Lubbock procured a few Elephant and other bones, but in a very im-

\* *Early Man in Britain.* 8°. Lond. pp. 155, 156. (1880.)

† *The Geologist*, vol. iii. p. 240. (1860.)

‡ *Quart. Journ. Geol. Soc.*, vol. xii. p. 124. (1856.)

perfect state. They were all found low down in the gravel—at the point where it becomes mixed with chalk-rubble, or on the top of the chalk itself. . . . The bones, as usual in such situations, although very friable, are tolerably entire, or if broken are not worn " (see also p. 357).

Further east the gravel seems to be continuous, and to slope up, from the level of the large ballast-pit near Taplow Station toward that of Taplow village, and therefore it seems likely that the "high-level gravel" of the section given by PROF. PRESTWICH may be merely a higher terrace of that at the railway, which latter itself belongs to a terrace many feet above the river. PROF. PRESTWICH says that the higher gravel is "very similar in many respects to that in the valley."

Around Burnham, Farnham Royal, and Stoke Poges there were many pits, some large, in the usual flint-gravel, which, rising gradually from the river, here reaches a considerable height above it. There are other sections of the gravel from Taplow, by Slough and Upton, toward Colnbrook, and also in the lower gravel-flat of Dorney, Boveney, Eton, Datchet, Horton, Wyrardisbury (or Wraysbury), and Colnbrook. Near Datchet the gravel is often hardened into a sort of breccia by the infiltration of a small quantity of iron-oxide.

At the brickyard north of the railway, S.S.W. of Burnham, there is light-brown or buff loam (brick-earth), 10 feet thick, above the gravel. There is a great spread of this from Slough towards Wexham and Langley Marsh, indeed eastward to the Colne, and just north of the first place, it is largely worked.

In the railway-triangle at Slough the cuttings show six or eight feet of brick-earth over the same thickness of bedded gravel, with water at bottom (1866).

MR. USSHER notes that "at Iver Green, below loamy soil, with flints and pebbles, there is gravel with layers of sand."

#### *Between the Colne and the Brent.*

This is by far the widest tract of gravel and brick-earth in the whole of the Thames Valley, and there are many small streams flowing through it. There is likely to be rather more brick-earth than is shown on the map: thus along the railway westward from Sunbury Station there is loam at the surface. When the Drift was mapped here no attempt was made to separate the gravel and the loam.

A spur of gravel spreads over Uxbridge Common northward to Harefield Lodge, and forms the top of the hill. This high terrace may perhaps be an outlier, separated from the lower gravel on the south by erosion through to the underlying London Clay in the higher part of Uxbridge, along a line parallel to, but a little above, the High Street. The gravel has been worn away along the valley between Uxbridge and Hillingdon, to a point a little south of the road; but it again spreads northward, over the higher ground, to Little Hillingdon, and thence south-eastward to the brook at Yedding Green, the boundary-line gradually falling to a lower level. The rectangular area of brick-earth between the last place, West End, and the canal has a doubtful boundary. On the other side of the canal the London Clay rises up from beneath; but further east a spur of gravel reaches northward to Greenford, and is cut off on the east by the Brent, which river has worn its way through to the London Clay as far south as Hanwell, if not further.

Around Hillingdon and Hayes there is gravel, shown in many pits; south of Uxbridge there is brick-earth as well; and at West Drayton, and thence to Southall, there is a great sheet of the latter, giving rise to many and large brickyards. Near Drayton the brick-earth is not very thick, mostly not more than six feet perhaps; and it has been quite worked out in many places, the gravel below having been thereby laid bare, and the level of the ground evenly lowered over areas of many acres. The shallow cuttings along the canal show both the brick-earth and the underlying gravel.

\* *Quart. Journ. Geol. Soc.*, vol. xii. p. 132.



Between Southall and Hanwell there is a great thickness of gravel, which may be well seen in some large pits where the Great Western Railway crosses the high road, and also in the cutting of the Brentford branch-line. Southward there is brick-earth at Spring Grove (Isleworth), and still further south gravel only.

Just after this Memoir was ready for printing MR. J. A. BROWN published a short account of the "Discovery of *Elephas primigenius* associated with Flint Implements at Southall,"\* in which he says "The remains of the Mammoth were discovered in Norwood Lane [in drainage-works], about 550 yards from its junction with Windmill Lane . . . in sandy loam, underlying evenly stratified sandy gravel, . . . brick-earth about a foot in thickness, surmounting the gravel—in all about 13 feet of river drift above the fossils . . ."

"There can hardly be a doubt that the bones of the whole of the fore part of the Elephant, if not of the entire skeleton, were in juxtaposition."

"Several flint implements were found . . . in close proximity to the remains . . ."

"From the adjacent excavations in the Windmill Road [Lane] several good specimens of Palæolithic work were also obtained . . . the underlying Eocene bed rises to within two or three feet of the surface a few yards west of the spot where the bones and implements were found."

At Staines, Hounslow Heath, &c. there is again gravel. There was a pit about a quarter of a mile south of Hanworth church, and gravel is shown in the railway-cutting at Hounslow Station.

At Hampton the map is imperfect just west of the village, where the gravel at the higher level, on the north of the road to Sunbury, is separated by a narrow outcrop of London Clay, on the slope directly south of that road, from the lower terrace of gravel which spreads from the foot of that slope to the marsh. The clay has been worked (for the construction of reservoirs at Molesey) in large pits on the northern side of the road near the western end of the Waterworks, and in December 1887 it was to be seen in section on the southern side of the road, by the then north-western corner of the works, where some extension was being made by the West Middlesex Company.

Further evidence is given by the shallow cutting on the Thames Valley Railway, north-west of Hampton, where, at the time the line was made, the gravel was wet at bottom, as if London Clay were near.

Gravel was shown beneath the alluvium, in making filter-beds, etc., for the waterworks (see p. 457).

The long cutting on the Thames Valley Railway westward of Teddington was not finished at the time of my visit, the middle part being untouched. The shallow north-eastern end, about half a mile S.W. of Strawberry Hill, is in gravel; but as the ground rises westward the London Clay rises up from below: it is dark grey, and with an almost continuous bed of septaria. The junction of the clay and the gravel is for the most part even, and only the very topmost part of the clay is discoloured brown. The gravel is evenly bedded, and a great quantity of water was thrown out from it by the underlying clay. The south-western end of the cutting is also in gravel, in parts cut through to the London Clay.

A fairly-marked terrace rises on the western side of the brook from Isleworth to Twickenham, and thence south toward Maude Cottage. It seems to be a gravel terrace; at Twickenham there is brick-earth on the lower ground at its base.

The following section of an excavation for the Hounslow and London Railway, just south of Osterley Park, made in 1881, has been recorded by MR. W. G. SMITH.†

River	{	Brick-earth, about 3 feet.
Drift.		Gravel, with horizontal layers of fine sand, and with a very large rude worked flint (2 feet long, 32 lbs. in weight).
		London Clay, 2 feet.

\* *Geol. Mag.*, dec. iii., vol. v. pp. 317-319. (1888); and since in *Proc. Geol. Assoc.*, vol. x., No. 7, pp. 361-372.

† *Nature*, vol. 28, no. 730, p. 617. (1883.)

*Between the Brent and the Serpentine.*

From Hanwell to East Acton the gravel ends off at the foot of the London Clay hill, except for some higher patches found by MR. J. A. BROWN since the survey was made; but thence eastward to Notting Hill the boundary-line of the valley-beds is somewhat doubtful, as the highest gravel terrace is there wanting, and it is the middle terrace of brick-earth that spreads over the London Clay. To make matters worse the brick-earth, generally very sandy, is here not unlike the stiff London Clay; however anyone who has shot at the rifle-ranges on Wormwood Scrubs after wet weather will never doubt that both soil and subsoil are of the stiffest clay.

It will be convenient to note first the high gravel observed by MR. BROWN, who says "near the junction between the Edgehill and St. Stephen's roads, [Castlebar Hill], there has been exposed a thick bed of gravel, sand, and loam, the approximate height of which is 160 feet . . . a similar gravel occurs further east, nearly on the same level, at the junction of the St. Stephen's and Castlebar roads, so that this gravel probably continues over the rise of the hill which intervenes . . . Similar gravels occur on the north slope of the hill,"\* and the following section is made up from his paper above quoted, and a note that he kindly sent me later of this "highest bed of the River Drift in the neighbourhood."

Soil	-	-	-	} to 10 or 11 feet.
Clayey gravel, stones small and subangular	-	-	-	
Clayey sand or sandy loam, mostly thin	-	-	-	
Sand and gravel, almost wholly of pebbles	-	-	-	

MR. BROWN is disposed to consider the pebbly gravel as of older date than the rest. He showed me some of the upper gravel (?), at the western edge of Castlebar Park, and this was certainly like the River Drift, whilst the description of the other reads like that of his "furrow-gravel" on the Mount (see p. 308).

The same observer has remarked that "At Acton wells there is a considerable patch of sandy gravel at the level of 106 feet O.D., the occurrence of which no doubt gave rise to the springs which obtained for these wells their old reputation."†

Near Hanwell, Ealing, and Acton the gravel was often seen in pits and railway-cuttings; there is also brick-earth, which has been worked at Ealing Common.

Some time after the publication of the Geological Survey Map and Memoir, the gravel of Acton and Ealing received much attention from GENERAL PITT-RIVERS (then COL. LANE-FOX), and no doubt, were the survey of that district to be again taken up, in the more detailed manner of our present work, and with the far better Ordnance Map now to be had, some changes would be made in accordance with his observations, especially as regards the outcrop of London Clay, in narrow strips, between the higher and middle terraces, an occurrence which is often to be looked for, but which I could not prove when mapping here.

In his description of this district‡ GEN. PITT-RIVERS says that "strips of London Clay . . . run round the patches of high-terrace gravel along the sides of the Thames valley, at an average height of 50 feet, dividing it from the mid-terrace gravel below. These strips . . . are seen at Hanwell, at Acton," etc. "Along the sides of all the tributary streams, the Brent, the Acton stream" etc. "this strip of the London Clay is also found at about the same general level of 50 feet."

Of the strip of clay south of Churchfield, just east of Acton, our author says "it is correctly given in Mr. Mylne's Map. I ascertained its existence by cuttings for sewers made in the lane to the eastward of the railways, and

\* *Quart. Journ. Geol. Soc.*, vol. xlii. p. 193. (1886.)

† *Paleolithic Man in N.W. Middlesex*, p. 51. *Lond.* 1887.

‡ *Quart. Journ. Geol. Soc.*, vol. xxviii. pp. 449-465. (1872.)

also in Grove Road; it consists of clay, with occasional irregularly shaped holes on the surface, filled with gravel."

The details of the sections observed by GEN. PITT-RIVERS will be given in an Appendix, and his find of flint-implements has already been noticed (p. 341).

MR. BROWN has remarked that "the variation in the thickness of the brick-earth series on the high-terrace gravels is very remarkable; the following is one striking instance. . . . On the line of the Avenue Road from Castle Hill Station, where the gravel reaches to the surface, and shows but small traces, if any of brick-earth above it, northward to St. Stephen's Church, the gradually deepening deposits of the latter formation are very noticeable. Commencing at the Pyrmont Road, it is found to be 6 feet thick at the Albany Road; it increases to a considerable extent at the Arlington Road, and develops to a thickness of over 21 feet near the Waldeck Road, with only about 2 feet of gravel underlying it . . . beyond this it becomes shallower and thins out to the north."

One of "The gravel-pits in the Creffield Road, Acton . . . near where that road is intersected by Mason's Green Lane, about 200 yards south of the bridge over the Great Western Railway," gave the following section, to a depth of 13 feet\* :—

Soil and Trail (agglomerated stones).

Brown brick-earth over sandy loam.

Bleached pebbles. Floor with a great number of worked flints (see p. 352).

Subangular gravel, with seams of sand.

Bleached pebbles, humus, and black matter. Flakes.

Coarse gravel, with seams of sand, and with two black seams.

Near Brentford, Acton, and Chiswick the terrace-structure may be well seen. I have traced the rise of the highest terrace from Drum Lane, by a little below Gunnersbury and Acton, to East Acton, where this terrace ends off and the next below, chiefly of brick-earth, takes up the whole space between Wormwood Scrubs and the Thames. The rise of the latter terrace I have traced from the river at Kew Bridge, by the north of Strand Green, where it is very well marked, to the south of Chiswick House, and thence to the river again at Chiswick.

The space south of this line, that is in the bend of the river between Brentford and Chiswick, belongs to another terrace (the lowest) of gravel, capped by a foot or more of light-brown sand.

The second or middle terrace is here the most important, owing to the wide-spread bed of brick-earth above the gravel, and is also interesting, from the fact of mammalian remains having been found in the gravel long before they were found in the higher terrace. The late MR. W. K. TRIMMER was, I believe, the first to make known this discovery, which was published in a posthumous paper on Organic Remains near Brentford,† from which we learn that his specimens came from two fields, not contiguous. "The first field is about half a mile north of the Thames at Kew bridge. The strata here are" as follows :—

[River Drift.]	{	Sandy loam, the lowest 2 feet slightly calcareous; 6-7 feet.
		Sandy gravel, a few inches, with land- and freshwater-shells and a few bones of small animals.
		Loam, slightly calcareous; 1-5 feet. Remains of ox and deer, and shells, as above.
		Small patches of peat, a few yards wide and a few inches thick, frequently occur here.
		Gravel, with water; 2-10 feet; always deepest where covered by peat, the lower part then being a mixture of clay, sand and gravel.
		Remains of elephant, hippopotamus, and ox.
Blue [London] clay, with pyrites, and nodules.		

\* *Quart. Journ. Geol. Soc.*, vol. xlii. pp. 194, 197. The section also in "*Paleolithic Man in N.W. Middlesex*," p. 56.

† *Phil. Trans.*, vol. ciii., pt. ii. pp. 131-134. (1813.)

"The second field is about one mile to the westward of the former, one mile north of the Thames, and a quarter of a mile eastward of the river Brent. The strata are"—

Sandy loam, the lowest 3 feet slightly calcareous ; 8 or 9 feet.

Sand, coarser towards the bottom, and ending in sandy gravel. Remains of hippopotamus, elephant, various deer, ox, and freshwater-shells ; from 3 to 8 feet.

Sandy loam, highly calcareous. Upper surface nearly level ; but the bed gradually increasing from a feather-edge to 9 feet thick. Remains of deer and ox, with land- and freshwater-shells.

Gravel and then clay, as in the above ; but only occasionally touched.

PROF. MORRIS has given an account of the beds shown in the cutting of the South Western Railway at Kew Bridge Station and of the fossils found in them,\* and from his paper the following section and remarks are taken, as the cutting must have been much clearer when seen by him than in 1860 (when I surveyed that neighbourhood) although part of it was then being widened :—

	ft.	
Vegetable mould	1	} about 20 ft.
Brick-earth, fine brownish loam	4	
Sand, bedded and false-bedded, with a little gravel	6	
Sand with clay and irregular gravel	1	
Ferruginous gravel and sand, with patches of clay	1	
Clayey sand and sandy gravel, with large flints here and there ( <i>Bones and Shells</i> )	1 to 2	
Ferruginous sand and gravel	1	
Light clayey sand and ferruginous gravel with boulders (pebbles <sup>†</sup> ) of quartz, granite, rock with <i>Ammonites</i> , &c. ( <i>Bones</i> )	6 to 7	
London Clay.		

"The section above given, although differing in minor details, presents similar general characters to those recorded by Mr. Trimmer as occurring in the clay-pits examined by him, one of which is more than a mile distant." It "gives the principal features of the deposit, as exposed in the deepest part of the railway-cutting, which extended for about a third of a mile, and presented great variations in the order and relative thickness of the sands and gravel, which pass into one another in a very irregular manner." Here, as at Hurley and Taplow (see pp. 389, 393), the bones were most abundant in the lowest bed. A list of the fossils, with those of other places above London, will be found at p. 336.

In an earlier paper PROF. MORRIS said that "In the excavations for the reservoir of the new water works close to Kew Bridge, similar strata [to those at Brentford, described by TRIMMER] were dug into, containing bones of the elephant, ox, and deer, with some lignite, but no shells . . . the thickness of the strata was about fifteen feet, and [they] reposed on the London clay, on the surface of which were found two large boulders of druid sandstone."<sup>†</sup>

At Coles Hole Pottery, just north of Kew Bridge Station, brick-earth and a little gravel and sand are found above the London Clay, which last is worked.

Over the greater part of the tract north of the high road from Turnham Green to between Hammersmith and Kensington the gravel is covered by the usual brown loamy brick-earth, only a few feet thick, so that in many places it has been worked away ; however, on both sides of the railway for some way south of Wormwood Scrubs, the brick-earth takes a new character, being a brown clay, rather like the London Clay (see also p. 395), but with layers of "race" and here and there of small flints, and sometimes slightly sandy. At one brickyard I was told that gravel had been found below some 10 or 12 feet of this, but that at another part 30 feet had been sunk through clay alone, the lower part being stiffer and of a bluish-grey colour (London Clay<sup>?</sup>, without gravel between it and the brick-earth).

This terrace extends to the Thames at Hammersmith, but there is a thin strip of the lowest terrace (gravel) along the river, from about three quarters

\* *Quart. Journ. Geol. Soc.*, vol. vi. p. 201. (1850.)

† *Ann. Nat. Hist.*, n. ser., vol. ii. p. 540. (1838.)

of a mile south of that place by Fulham church to between Parson's Green and Sandy End, where it seems to run as a spur up toward Walham Green, and then to the Thames at Cremorne. Of course this line is that of the rise of the second and principal terrace, which seems again to form the river-bank at Chelsea.

At the top of Notting Hill there is a high terrace of gravel, separated from the lower terrace of Kensington by a narrow strip of London Clay, laid bare by erosion through the gravel from Holland House eastward, above the High Street, to a little west of the Gore; perhaps even further east, as shown in Mr. R. Mylne's map, in which this strip of London Clay is carried on to that just south of the Serpentine. This terrace is the cause of the springs and moist ground in the southern part of Kensington Gardens, where the water is thrown out from the gravel by the underlying stiff clay. At Notting Hill the gravel does not seem to spread far to the north of the Bayswater Road.

In pits dug for the foundation of a house on the northern side of the Bayswater Road I saw many feet of coarse light-coloured sand.

The gravel has been cut through for a short way down the Serpentine valley, there being a very narrow outcropping fringe of London Clay along the western edge of the water in Kensington Gardens. It is this latter formation of course that holds up the water of the Serpentine; and it again comes to the surface at the eastern end of the lake, and separates two terraces of gravel from Hyde Park Corner, through the Green Park and on the south of Piccadilly, to near Charing Cross, making a slight rise of the ground along that line. The Museum in Jermyn Street, the head-quarters of the Geological Survey, is, I believe, partly on the gravel, of the higher terrace, and partly on the clay. In Mr. Mylne's map the latter is coloured some way up the hollow that runs across Piccadilly: this may be right, but I do not know on what evidence it rests.

"In the very deep cutting on the Metropolitan District Railway, between Gloucester Road and Kensington High Street, the gravels are small [fine], sandy, and cross-bedded."

"The excavation for the foundation of the wall [of the embankment north of the Thames between Chelsea and Albert Bridges] runs along the edge of the beach at about the margin of ordinary low water. For a large portion of the distance there is not much more than 1 foot of extremely coarse gravel above the [London] clay. Here and there occurs a pocket of some 3 feet . . . A few yards further in the stream, where the cylinders of the Albert Bridge are being fixed" the section, beginning 22½ feet below Trinity high water mark, was:—Coarse gravel 4 feet, and fine gravel a foot, over London Clay, whereas "at the Cylinders on the south side we have a greater deposit," beginning 15 feet below Trinity high-water mark, the coarse gravel being 10 feet thick.\*

According to Mr. W. WILSON,† in making the Victoria Bridge the London Clay was found in the river-bed at an average depth of 30 feet below Trinity high-water mark, capped by gravel of an average thickness of 7 feet in the middle of the river and towards the south, but increasing to 25 feet thick at the northern shore.

#### *Between the Serpentine and the Fleet.*

The boundary-line follows the course of the Serpentine brook northward as far as the Great Western Railway, whence eastward by Paddington to the southern part of Regent's Park it is doubtful. In Mr. Mylne's map the gravel is coloured farther to the north than on the Survey map, perhaps rightly. From Regent's Park the boundary runs eastward to Euston Square, beyond which the tunnel of the Metropolitan Railway is in London Clay, the gravel having been worn away along the valley of the Fleet, from King's Cross towards Blackfriars Bridge.

On the northern side of the Serpentine at its eastern end the gravel comes down to the water, as the cutting for the large sewer (main drainage works),

\* HUDLESTON and PRICE, *Proc. Geol. Assoc.*, vol. iii, no. 1, pp. 62, 63. (1873.)

† *Proc. Inst. Civ. Eng.*, vol. xxvii, p. 57.

but a few yards from the edge, showed a great thickness of gravel. Further west, however, the London Clay comes to the surface for some way up the little hollow, and then, as on the other side of the lake, forms a narrow damp fringe, between the gravel and the water, to the Bayswater Road.

The following notes of the sections shown along the St. John's Wood branch of the Metropolitan Railway were taken in 1866.

I was told that there was nothing but stiff London Clay from the northern end, along the Finchley Road, to the top of Park Road (St. John's Wood). At the road just north of the Regent's Canal I saw, over the London Clay, a little gravel (chiefly of pebbles) below a few feet of brown clay, much like London Clay. Southward, where the railway comes close to Park Road there are pipes of this gravel going down to a depth of about 15 feet. Just south of Clarence Gate the following beds were shown, but the cutting was not then finished :—

Made ground and a little loamy earth.

Gravel, chiefly of pebbles.

Brown sandy clay, bedded in parts, from 2 to 6 feet (dies out, or is cut off, just to the south), passing into the bed below.

Buff and brown sand, false-bedded, clayey in parts ; with a mass of clayey gravel (chiefly pebbles) at one part ; not bottomed.

In making the tunnel for the Metropolitan Railway, a great thickness of gravel was found the whole way from Paddington to Euston Square. In most parts much water was thrown out from the gravel by the underlying clay, making constant pumping needful. Details of the section along this railway will be given in an Appendix.

In the excavations for the foundations of the Langham Hotel, Portland Place, below the "made ground" about 15 feet of sand and gravel were dug through. The sand was in excess, and both were bedded and false-bedded. There was much black earth in the sand, and the gravel was at one place quite blackened by it.

Gravel and sand have been shown by the excavations for sewers, &c. along Tottenham Court Road and Oxford Street.

In 1728 SIR HANS SLOANE noticed the occurrence, in his collection, of "the *dens exertus* [tusk] of an Elephant, which was taken up, 12 Foot deep, from among Sand, or Loom, as they were digging for Gravel by the End of Gray's-Inn-Lane, near London."\*

SIR R. OWEN states that "a large vertebra of *Balæna mysticetus* [whale] was discovered 15 feet below the surface, in gravel, by the workmen employed in digging the foundation of the new Temple Church."†

The sections shown by the excavations over the site of the Courts of Justice were observed from time to time by MR. W. H. HUDLESTON and MR. F. G. H. PRICE, from whose paper thereon the following account and figures are taken.‡ They remark that the area is nearly a square of about 500 feet, and that the deposits shown were as follows :—

*Brick-rubbish and made ground.* Consisting largely of the materials of previous houses, decaying, and being built over during a long time. This was of irregular thickness, many old foundations projecting into the gravel beneath. Many old wells were found.

*Gravel and Sand.* Very little in the way of fossils found : horns of *Bos* and *Capra* (?) jaw of horse, and greywethers occurred ; but the horns were not of species found in the gravel, and may have fallen in. In one place there was a layer of black sand, coloured by manganese-oxide.

*London Clay.* The uppermost part brown from oxidation ; the rest blue, with septaria, pyrites, Teredo-bored wood, and other fossils, including the new species *Fusus nitidus* and *Pleurotoma varicosa*. Fossils not in great number, and most much pyritized.

They give two general sections, which are here reproduced, in figures 71, 72. These are practically along the eastern and western sides, down the slope toward the Strand, and of course, therefore, that slope is represented in opposite directions.

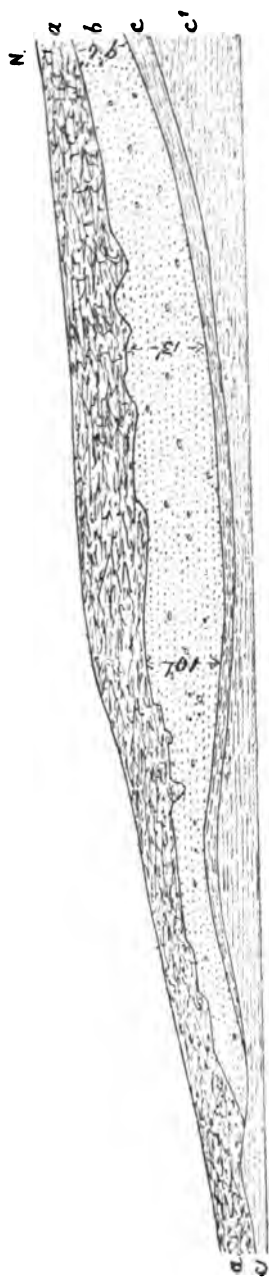
\* *Phil. Trans.*, vol. xxxv., no. 403, p. 458, plate.

† *Rep. Brit. Assoc.* 1842, p. 72, and "British Fossil Mammals," 1846.

‡ *Proc. Geol. Assoc.*, vol. iii., no. 1, pp. 43-64, pl. ii. (1873.)

Figures 71, 72. General Sections on the Site of the Courts of Justice, Strand (HUDLESTON and PRICE).

Length of each 500 feet. Vertical scale much exaggerated.



Eastern Side, parallel to and near Bell Yard.



Western Side, Clement's Inn.

- a. Brick-rubbish.
- b. Gravel and sand.
- c. Brown London Clay.
- c'. Blue London Clay.

It is notable how, in both sections, the gravel is cut off by the made ground; and the authors say that "this would also appear to be the case all along the lower or Strand face of the excavation, a little gravel in occasional hollows of the clay alone being noticeable."

In the eastern section "the curve of the London Clay surface . . . is, as regards the S. part, obtained from actual observation . . . The northern portion of it is assumed from test hole measurements." The rising of the London Clay at the southern end is remarkable, and leads one to think that there is a narrow outcrop of the clay along this part of the Strand. "That the clay forms the original surface here without any covering of gravel, may be inferred from the traces of tree roots which are still obvious [1873] at considerable depths. The name Holywell Street likewise is suggestive of springs in these parts, which rather points to a similar conclusion" . . .

"A section from E. to W. parallel to the Strand would show a great . . . swelling which the London Clay makes through the middle of the area [N. and S.], attenuating the gravel on either side, and almost cutting it out altogether"

"This swelling divided the works into two distinct systems of drainage."

In the western section the gravels were more sandy, and the thickness of 13 feet is given from a trial-hole.

In the following remarks, by the REV. PROF. W. BUCKLAND, the alluvial beds seem to have been disregarded:—"The site of the Abbey and adjacent parts of Westminster, between the Thames and the lake in St. James's Park (which was once a swampy creek, crossing between Charing-cross and Whitehall, into the Thames), is a peninsula of the purest sand and gravel, which may be seen in the foundations of the Abbey, and in new deep graves in the church-yard of St. Margaret."

"The surface of this peninsula is several feet above high-water mark; its north frontier is marked by the steps ascending from the Horse Guards Parade to Duke Street, and by the Terrace, covered with houses, on the south of Bird-cage Walk, whence it extends under Wellington Barracks to Buckingham Palace Gardens and Hyde Park."\*

### *Between the Fleet and the Lea.*

On the eastern side of the valley of the Fleet a bay of London Clay runs some way along and east of the Lower Road, Islington, and a spur of brick-earth, with a doubtful boundary, runs out from Islington over the New Cattle Market. In Mr. Mylne's map the brick-earth and gravel of Islington, &c. is cut off from the main mass, and shown as surrounded on all sides by London Clay. I cannot say that this is not the true state of the case, the ground being covered with houses, but the balance of probabilities seemed to me to be against it. Mr. Mylne also gives the brick-earth of Copenhagen Fields a further range westward than is shown on the Survey map, and this I am more inclined to agree with, from having seen in the collection of the late Mr. Wetherell, of Highgate, some bones of *Elephant* and of *Hippopotamus*, with which was the following note, written by him in 1857:—

"Fragments of bones . . . were found about 15 years since in digging for a sewer on the side of the road leading from Holloway to Camden Town, and near Brecknock Crescent. The bed in which they occurred was only a few feet from the surface, and rested on the London Clay."

\* A sermon preached in Westminster Abbey on . . . April 23, 1848. 8vo. Lond., 1848. Notes p. 24.



From Highbury the boundary-line runs north-eastward, the brick-earth and gravel forming the rising ground of Highbury, Stoke Newington, and Stamford Hill. The gravel is cut through along the small valley of the former Hackney Brook, and also along the valley of the Lea to Homerton.

During the widening of the North London Railway, in 1869, the cuttings were re-opened, and I was enabled to note the following sections: At the bridge east of the Caledonian Road there is London Clay only, and this clay seemed to be at the surface, except for made ground, at the Liverpool Road. Eastward however a thin bed of gravel comes on above, and before reaching Highbury Station is in its turn capped by brown brick-earth. London Clay crops out in the cutting between the third and second bridges west of Newington Station (the old one, now Mildmay Park?) and at the latter is covered at one part only by a deposit of bits of bricks, cinders, &c., perhaps the refuse-heap of an old brickyard.

MR. H. B. WOODWARD tells me that "only a thin and possibly scattered covering of gravel extends over Highbury Hill south-westward to Highbury Terrace." May not this be a stony top to the brick-earth near Highbury, which is very thick, sometimes nearly 30 feet of it having been found; at one of the brickyards it was capped by a clayey gravel, and underlain by sand and gravel; and at another it was somewhat bedded.

In 1868 MR. A. TYLOR noticed the occurrence of freshwater-shells in the brick-earth at the more eastern of the two pits then open at Highbury New Park, giving some details of the deposit; and the following account is compiled from his letter.\*

The older and more western pit showed well-marked beds of purple clays, with much wood, but no shells were found. At a depth of 40 feet false-bedded yellow sands occurred, 10 feet thick and rather like the Cyrena-sands at Crayford.

At the newer and more eastern pit there were some shells in the reddish loam immediately above the clay-bed, which occurred at the depth of 22 feet, was 2 feet thick and full of land- and freshwater-shells, with much wood. The fossils are noted in the general list (p. 337). They were named by PROF. R. TATE who remarked that the "assemblage of species suggests a shallow pool or a slow running stream of slight depth, on the margins of which semi-aquatic plants grew, affording shelter for the land snails."

This brickyard was close to Aden Terrace and about 400 yards east of Highbury Barn Tavern. There were also brickyards on the northern side of the North London Railway near Newington (now Mildmay Park) Station, south of which there is brick-earth, gravel, and sand. The great quantity of the last in this neighbourhood is noteworthy. The brick-earth is here worked away, so that the foundations of the houses (built of the bricks made from it) rest on the gravel below.

MR. A. TYLOR has given the following section of "the Stoke Newington pit, which is 43 feet deep":—†

? Soil.

{ River Drift. }	Large flints in brown clay, 6 to 8 feet, indented into the bed below.
	Brick-earth, finely laminated loams and clays, with a layer of black
	peaty clay about the middle. The shells (list p. 337) came from
	above the black bed; 30 feet.
	Yellow false-bedded sand.

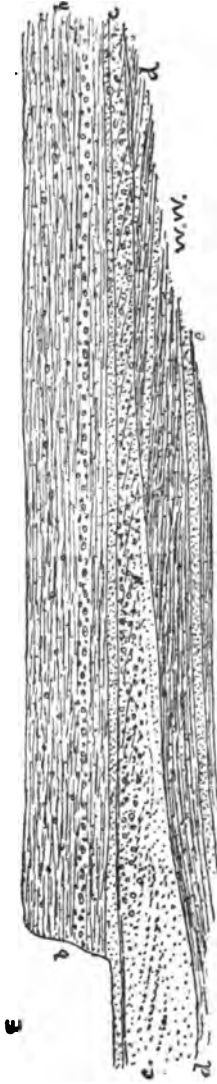
At Stoke Newington, on the western side of the high road, between Church Street and Victoria Road the section shown in fig. 73 was to be seen in 1865.

\* *Geol. Mag.*, vol. v. pp. 391, 392.

† *Quart. Journ. Geol. Soc.*, vol. xxv. p. 95. (1869.)

Figure 73. Diagram Section of Part of a Pit at Stoke Newington.\*

Scale about 16 feet to an inch.



	Feet.
a. Top soil (cut away at the part where the drawing was made)	about 1
b. Brown brick-earth, with scattered flints etc., and an irregular gravelly bed a foot or more above the bottom	about 7
c. Light-coloured sand and gravel, with loamy layers in the top part; from next to nothing to about 7 at the expense of c, by the addition at top of a little more loam and a second sand parting.	2 to 4
d. Brown loam, with small snail-shells, and a fragmentary large bivalve ( <i>Anodon</i> ?); this thickens at the expense of c, by the addition at top of a little more loam and a second sand parting.	over 1
e. Sand and loam, of which there is shown	

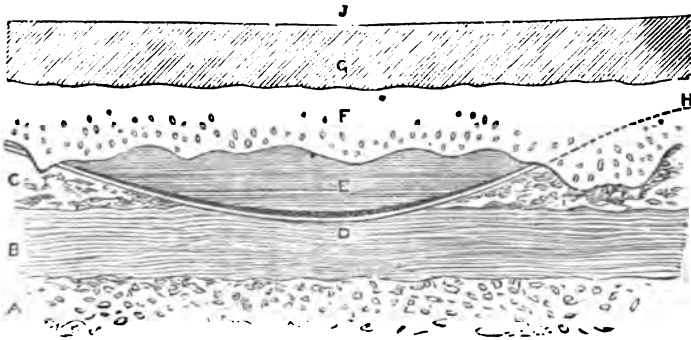
\* Although drawn as if in one line, for convenience sake, the section was not really so, there being a nearly right-angled turn about a third of the distance from the right.

In another pit just westward, there seemed to be sand with layers of loam, and gravel.

The cutting on the Great Eastern and Metropolitan Railway just south of Newington Common showed sandy gravel, which seemed to be replaced southward by bedded and false-bedded sand; whilst a brickyard close by, but still further south, gave a section of brick-earth over sandy gravel. At that time (when the railway was made) the brick-earth had been worked off a great part of this neighbourhood.

MR. WORTHINGTON SMITH has recorded a section showing that "an underground bed of a Palæolithic brook exists in Bayston Road, close to West Hackney Church, Stoke Newington High Street,"\* and he has kindly enabled me to reproduce his figure of the section (74).

Figure 74. Section through the Bed of a Palæolithic Brook, Stoke Newington (W. G. SMITH). Scale 6 feet to an inch.



J. The lowest point of Bayston Road, where the London Clay is 27 feet down.

G. Soil.

F. Warp and Trail.

E. Fine horizontally bedded sand.

{ Dark line, clay with sand.

{ Deep red sand, resting on red gravel, at D.

C. B. A. Beds of implementiferous gravel and sand.

"A few yards off, in the direction of H, the bank of the brook was again exposed, untouched by "warp and trail.""

MR. SMITH adds that "London clay comes to the surface close by and towards the north-west; nothing is more common than to see seams and rolled blocks of this clay in the sand and gravel . . . sometimes implements may be found sticking in this transported clay."

In 1854 PROF. PRESTWICH described a fossiliferous deposit in the gravel at West Hackney, from which the following account is compiled.† The section was in a gravel-pit at Shacklewell Lane, a quarter of a mile east of West Hackney Church, and the beds seen were as follows:—

Brick-earth, removed here, but worked in an adjoining pit; 2 to 3 feet.

Ochreous gravel; consisting of subangular flints, some large flints hardly at all worn, flint pebbles, a few pebbles of quartz and of sandstone, and some rolled pieces of hard sandstone [? greywethers], with irregular layers of ochreous and yellow sand; 6 feet. Resting on a slightly waved surface of the bed below, and at one place slightly indenting it.

Dark grey, more or less sandy, laminated clay, full of small, broken branches and leaves of trees; here and there with parts of stems and trunks of oak, elm, alder and hazel, some 3 or 4 feet long and 6 to 12 inches in diameter,

\* *Journ. Anthropol. Inst.*, vol. xiii., p. 361, pl. x., fig. 7. (1884.)

† *Quart. Journ. Geol. Soc.*, vol. xi. pp. 107-110. (1855.)

their texture generally little altered, and all prostrate, but in various directions; some bones (P of ox) at the base, and many fragile and fragmentary land- and freshwater-shells of recent species (see list, p. 337). Only occasionally exposed. 2½ feet.

Light-coloured and ferruginous sand and gravel (subangular flints, with a few flint pebbles), in the upper part of which shells (like those above) were said to have been occasionally found; not bottomed.

At Dalston Station, North London Railway, the junction with the old line on the west showed brown gravelly loam over light-coloured sandy gravel; south of the station there was gravel; and at the other junction with the old line, on the east, the gravel was mostly capped with made ground.

Crossing now to the other side of the former Hackney Brook, the cutting on the Great Eastern Railway, just north of the old brook, is in gravel, with London Clay at the bottom (bricked up at the time of my visit). I was told that many shells were found in sand, at the base of the gravel, and a small heap of this sand was full of *Corbicula fluminalis* and other shells. The section further north has been thus recorded by MR. WORTHINGTON SMITH.\*

"During the formation of a branch line of Railway a cutting has been made across the eastern side of Hackney Downs, in which . . . stratified gravels and sands, with occasional partings of sandy marl are exposed to the depth of eight or ten feet. I could not detect any fossils in these beds, but in a shaft sunk immediately to the east . . . a short distance from the Downs Road, I am informed that twenty-two feet of gravel, etc., was penetrated before the London clay was reached."

"The lower portion, consisting principally of beds of sand, contained fluviatile mollusca abundantly, and in a good state of preservation. In the course of a few visits . . . I succeeded in collecting (from the sands, etc. brought up the shaft) the . . . species of land and freshwater shells" in the combined list at p. 337.

To MR. SMITH we are also indebted for figs. 75, 76, from an excavation "270 yards west by north from Clapton Railway Station, and just south of Caroline Street," which "show admirable sections of characteristic "warp and trail,"" as he calls the irregular surface-deposits. Other neighbouring sections by MR. SMITH have already been given, pp. 346, 347.

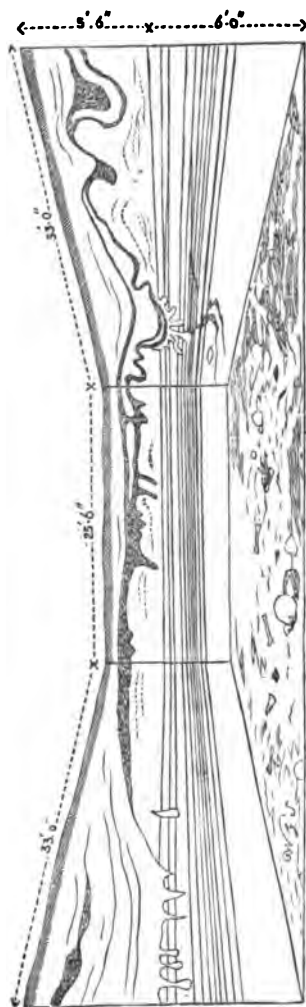
At the brickyard east of Clapton Railway Station "the brick-earth is rich in Mammalian remains," according to the same authority.†

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\* *Geol. Nat. Hist. Repertory*, vol. i. p. 373. (1867.)

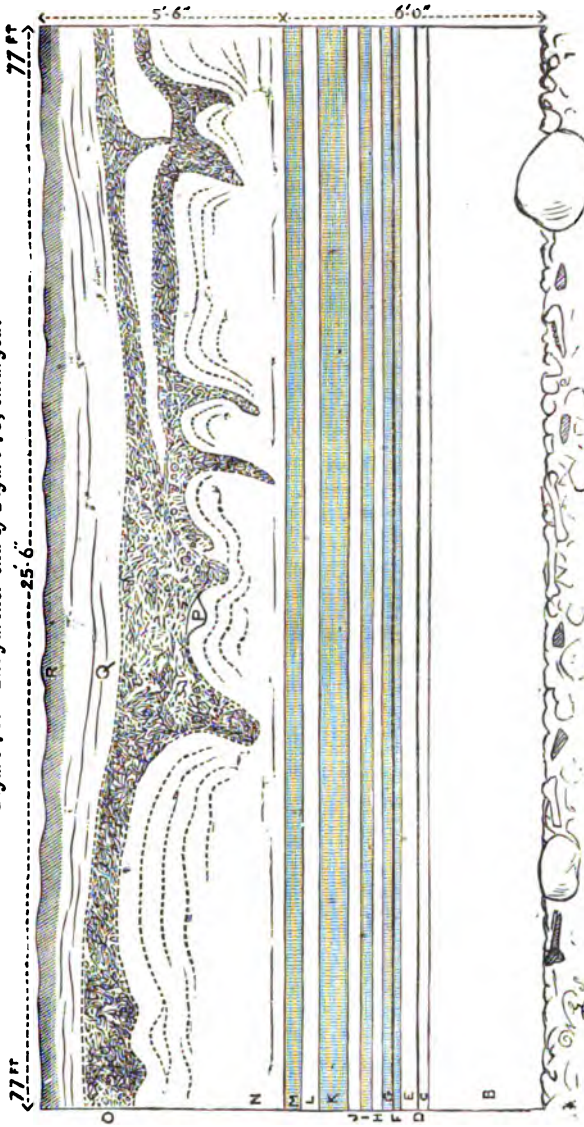
† *Proc. Geol. Assoc.*, vol. viii., no. 3, p. 136. (1888.)

Figure 75. Section S. of Caroline Street, near Clapton Railway Stations. (W. G. SMITH.)  
Facing South.



Showing undisturbed beds of sands and loams, with gravel at the floor of the pit, overlain by contorted sands, loams, etc.

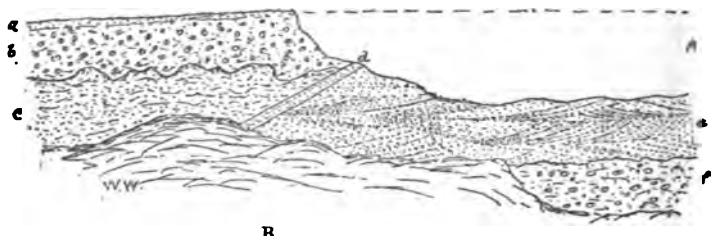
Figure 76. The further end of Figure 75, enlarged.



- R. Soil.  
 Q. Mud belonging to the trail.  
 O. Trail.  
 P. A pocket of London Clay (transported).  
 N. Sand and loam, crumpled and disturbed.  
 M, K, G. Dark sands and clays.  
 A. Gravel, with sub-abraded implements, chiefly in the upper part, mammalian remains, drift-wood, &c., immense blocks of sandstone, some 2 feet across, some showing glacial striae.
- L, H. Light-coloured sands and clays.  
 J, E. Yellow sand.  
 I, F, D. Red sand.  
 C. Almost white sand.  
 B. Buff sand, sometimes full of land- and freshwater-shells.

The large gravel-pit on the western side of the North London Railway where it crosses the great sewer at Old Ford, showed (in 1863) a varying section of gravel, &c. At the eastern end of the southern side I saw about 20 feet of gravel, with lenticular masses of grey, coarse, false-bedded sand with flints, which thickened westward, where there were also clayey beds, until they made up half the section: at the western end there was some messy brick-earth over the sand and a little gravel over the brick-earth. At this end, turning to the north, was the section shown in fig. 77:—

*Figure 77. Section in a Gravel-pit near Old Ford.*



Scale about 16 feet to an inch.

	A. Ground cut away	B. Fallen earth.	FEET.
a. Soil.			
b. Irregular, sandy gravel -	-	-	about 5
c. Brown brick-earth, as much shown as	-	-	6 or 7
d. Thin oblique layer of bedded brick-earth.			
e. Bedded and false-bedded, light-coloured sand, as much shown as			about 9
f. Sandy, bedded gravel, to a depth of	-	-	4

At another part there was sandy gravel resting irregularly (as in the figure) on bedded, sandy brick-earth, of a good thickness, and underlain by sand near by; whilst further east the upper gravel was almost replaced by sand, and still further the brick-earth got more sandy, and then the two layers of sand came together, and there was little but sand from top to bottom (at the eastern end of the northern side).

## CHAPTER 23. RIVER DRIFT.

## VALLEY OF THE THAMES, ESSEX.

*Between the Lea and the Roding.*

Though taking up a large space here the River Drift is not shown in sections of importance, nor is there much variety, only gravel and sand being seen, with slight exception.

The masses of the higher terrace at Walthamstow and Wanstead occur as isolated patches, divided from the larger terrace below by strips of London Clay.

In a pit about a third of a mile south-eastward of Walthamstow church the gravel was pebbly.

The road-cutting at Snaresbrook Railway Station showed vertical junctions of gravel and London Clay: that the former here fills pipes in the latter is also proved by a pit having been dug in the gravel below its general boundary-line, on the slope from the northern part of Wanstead towards the Roding.

A lower terrace occurs from the west of Walthamstow south-eastward to Leyton, where it is barely divided from the broad Stratford mass by denudation along the little tributary-valley. A terraced structure occurs from about where the road on the north (to Tottenham) enters the marshland south-eastward to near Leyton House, and the still lower mass west of that line is clearly a gravel of the Lea.

From the south of Leyton the boundary-line runs north-eastward, up the little tributary-valley to Leytonstone, and then eastward to the Roding below Wanstead, all the space between this line and the marshes of the Lea the Thames and the Roding being taken up by gravel, except for the little brick-earth that has been worked at the northern part of Epping Lower Forest, and for a small patch seen rather more than a mile S.E. of Plaistow Railway Station.

In a pit, for ballast, on the southern side of the great sewer-embankment at Plaistow, just west of the main street, the following section was shown (1863):—

Gravel, of subangular flints and flint-pebbles, greatest thickness, 10 feet.

London Clay, greatest thickness 8 feet.	{	Brown clay, a foot to 2 feet, with a little blackish clay
		at bottom at one part.
		Bluish-grey clay, with a layer of septaria.

The junction of the gravel and the clay was slightly waved, and the irregular, brown, upper part of the latter of course owes its colour to the infiltration of water through the gravel and the consequent alteration of the colouring-matter.

There was another large gravel-pit on the northern side of the embankment; another further north, in which the clay was touched at bottom; and another on the southern side further east, in which the clay came almost to the surface of the ground in parts, the junction with the gravel being irregular; here at the lower (eastern) end brick-earth also occurs.

At the bridge, on the main line of the Great Eastern Railway, over the western branch of the Roding, westward of Ilford, the following section was



noted by DR. J. MITCHELL, in 1838, from the excavation for foundations. It is taken from his MSS., the use of which was kindly granted me by PROF. PRESTWICH, and it seems to show that the fossiliferous brick-earth has here set in :—

Gravel ; 3 feet.

Yellow sand ; 4 feet.

Brown clay with crushed shells ; a foot.

Blue clay with crushed shells in masses adhering together ; 2 feet.

Yellow sand ; 3 feet.

On the eastern side of the bridge there was the same succession, except that instead of gravel was peat-moss with trunks and branches of trees (Alluvium).

*Between the Roding and the Ingrebourn.*

In this tract, as in that to the west, there are detached masses of a higher terrace of gravel on the north. These higher patches are separated from the rather lower sheet to the south by an outcrop of London Clay, partly very narrow.

A large mass stretches irregularly eastward from near the Roding opposite Wanstead, by Barking Side and Aldborough to the south-eastern part of what used to be Hainault Forest, by Padnal Gate, and northward to Fairlop Plain. In this large mass it seemed as if the London Clay came up through the gravel in places, as half a mile and more south-westward of Barking Side, between that village and Aldborough, and round Aldborough Gate.

Perhaps the bay, mapped as joining on to the lower sheet just north-westward of Romford, may belong to the higher terrace, for indications of clay were not wanting some little way north of the high road. Similarly I feel some doubt (from the levels) as to the mass between Romford and Hornchurch, and should not be surprised if the highest part of it were separate from the rest, and the smaller promontory east of Hornchurch may also be separate, for a like reason.

The late DR. J. MITCHELL recorded the following section on the Great Eastern Railway, at the foundation of the bridge over the line, for the road from Hare Street southward\* :—

Vegetable mould ; a foot.

[River Drift.] { Gravel ; 10 feet.

{ Sand, with water, the bottom foot with flints ; 12 feet.

Blue [London] Clay ; 10 feet.

I noted, in passing through, that at the eastern end of the same cutting there was also gravel and sand over the London Clay.

The great sheet of Drift that reaches from north of Ilford to near Hornchurch is chiefly gravel, but with some cappings of loam here and there. It is cut through, to London Clay; in places along all the streams that flow across it, and there are occasional signs of a terraced structure; as on the south of Barking and of Chadwell Street. The chief interest centres in the fossiliferous deposits of Ilford, which have yielded such numbers of Mammalian remains, for the preservation of so many of which we are indebted to the zeal and to the liberality of the late SIR ANTONIO BRADY,† whose collection is now in the British Museum.

PROF. MORRIS seems to have been the first to record the sections here, which he did as follows :—" There are three principal brick-fields, the first .

\* From his MSS., in the possession of PROF. PRESTWICH.

† See " Catalogue of the Pleistocene Vertebrata, from the Neighbourhood of Ilford, Essex, in the Collection of Sir Antonio Brady . . . ." by W. DAVIES. With an Introduction by SIR A. BRADY. Pp. xvii., 75. Privately printed. 8°. Lond. 1874.

. adjoining the river Roding; the second . . . about five hundred yards from the river; and the third . . . beyond the town on the left [northern] side of the road. The strata of the three fields are nearly the same, merely varying a little in thickness in each," and he then gave an average section, noting the occurrence of bones and of shells.\*

The second of these brickyards seems to have been abandoned long ago. The first is the one generally known as the Uphall pit. The third is that cut through by the railway.

Some years later DR. R. P. COTTON gave a fuller account of the Ilford pits, with detailed sections of two, but none of the other (Morris' second)†; and from his paper the following general remarks are taken :—

"The stratification of the clays is generally regular and horizontal, the layers however frequently thin out or expand, but the veins of sand are irregular and waved, so that the surface of the cutting, from the changing thickness of the strata, varies extremely within the distance of a few feet, although the general character is the same; in some places the sands and clays pass into each other, but they are more usually distinct."

"In a well lately dug in the neighbourhood, sand and gravel with irregular layers of clay were met with to a depth of 50 feet."

"A perfect elephant was gradually discovered by the labourers a few months back."

"The nodules termed by the brickmakers "race" are of various sizes, from that of a marble to an orange, and occasionally very much larger . . . a careful analysis has shown me that they are composed almost entirely of carbonate of lime, with a slight addition of phosphate and sulphate of lime, a little phosphate of alumina, silica, and peroxide of iron . . . Vegetable remains are scarce, but a large bed of lignite was discovered in the brickearth some time back."

"The circumstances under which the bones are discovered lead to the conclusion that the animals lived and died near the spot . . . the skeletons are frequently entire and have not suffered by attrition."

"The strata were evidently quietly deposited, the shells are in general well preserved, and the stratification of the sands indicates the long continuance of causes alternating with one another and uninterrupted by violence."

"The association of the remains of the Beaver, Megaceros and Red Deer with those of Mammoth and Rhinoceros is interesting, as it would show, that whatever the physical conditions were under which these animals were destroyed, they could not have been violent or universally destructive."

Turning now to the details of the sections, it is clear that these have varied a good deal, from time to time: indeed they may be seen to differ in different parts of the same set of pits. Whilst my own notes have been taken at various parts separately, it seems as if other observers had grouped their notes into general sections of each of the two pits. At the risk of some slight repetition it may be well to give some of these various records.

Beginning with the more northerly brickyard, on the north of the high road, just east of Ilford, and divided by the railway, DR. COTTON's section, from the paper above-quoted, is as follows :—

Soil with gravel; 2 feet.

Coarse gravel; 2 feet.

Coarse yellow stratified sand; 4 feet.

Brown brick-earth, regularly stratified with nodules of race, and a few bones; 5 feet.

Light-brown brick-earth, interstratified with layers of sand and full of bones; 3 feet.

Thin veins of yellow and brown fine sand, irregularly waved; 2 feet.

Coarse gravel and sand.

My own notes were taken in 1863 and in 1867, in which years the clearest parts were in different places, there being many separate sections. As far as possible each bed is marked by the same letter in the following details.

\* *Mag. Nat. Hist.*, n. ser., vol. ii. p. 540. (1838.)

† *Ann. Nat. Hist.*, vol. xx. pp. 164–169. (1847.)

Taking first the part north of the railway, in 1863 the section below was noted, on the northern side of the yard :—

Soil; 2 or 3 feet.

*a* { Irregular brown gravelly sand; 3 to 5 feet.  
Brown bedded sand; about a foot.

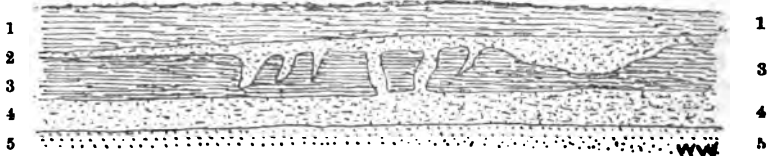
Clayey sand and loam; 1 to 4 feet.

*b*. Brown clay; shown to 3 feet.

At the western end of the yard, in 1867, sand with gravel (*a*) was seen over brown clay (*b*).

Near the eastern end a clear cutting in the upper part gave, in the same year, the section shown in fig. 78.

Figure 78. Section in the Brickyard east of Ilford.



Surface earth.

1. Dark brown clay, 3 feet or so.

2. Brown loam, from less than a foot to 3 feet; where thickest the lower part being sand; with small pieces of flint; upper surface flat, lower one irregular; filling cylindrical pipes in, and nearly through, the bed below.

3. Dark brown clay, with race and bones in the lower part, 3 or 4 feet at most. Westward this is less distinct and passes into the loams.

4. Brown loam, about 3 feet.

5. Lighter-coloured more sandy loam. } *c*

At the eastern end the beds shown were as follows :—

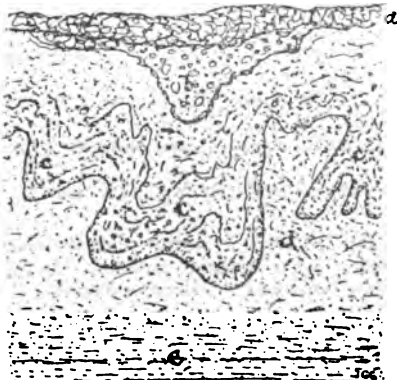
*b*. Brown clay and brown loam, together 8 feet, with race and a few pieces of flint, seeming to rest irregularly (in waves) on the next

*c* *f*. Brown bedded loam, of a lighter colour, more sandy and with thin partings of sand, as much as 9 feet in parts. Close by this is half made up of layers of sand, some false-bedded.

*d* ?. Sand seems to occur below.

MR. GOODCHILD has given me a sketch of the disturbed upper beds in this yard, from which fig. 79 has been made.

Figure 79. Section in the Brickyard at Ilford. N. of the Railway. 1888. (J. G. GOODCHILD.) Scale about 10 feet to an inch.



*a*. Soil, &c.

*b*. Gravel.

*c*. Contorted stony leam, folded down into the upper part of *d*.

*d*. Brickearth, without evident lamination.

*e*. Brickearth with lamination undisturbed.

The letters in this case, and in fig. 80, have no reference to those in the other sections.

At my earlier visit the clearest part of the pit south of the railway was close to the line, the section seen being :—

Soil and a little gravel (*a*); about 2 feet.

Brown clay; about 3 feet.

Lighter-coloured, more sandy clay; about a foot.

Brown clay, in parts bedded, with race and pieces of flint (chiefly in the lower part); passing down into the next; about 4 feet.

Brown, sandy clay, gravelly at bottom at one place; resting irregularly on the next; about 3 feet.

Buff, sandy loam; shown to a little over 6 feet.

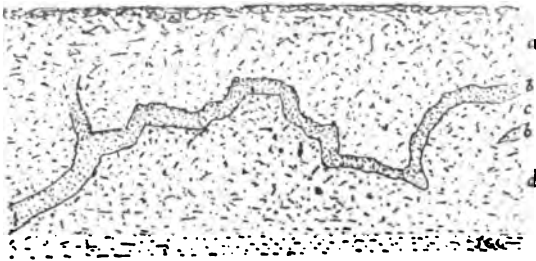
? Sand (*d*) below.

Later, at the western end, two shallow cuttings at the bottom of an old pit showed, the one bedded sand (*d*) and the other, which was slightly lower, gravel, most likely a bed below the sand.

MR. S. V. WOOD, Junr., has said of this pit that the brick-earth "may be seen . . . resting in one part direct on the London clay."\*

The following section, drawn at the eastern side of the larger and newer brickyard (not seen by me), on the south of the high road, has also been contributed by MR. GOODCHILD.

Figure 80. Section in the Brickyard on the Southern Side of the High Road, Ilford. 1888. (J. G. GOODCHILD.)



*a.* Soil, etc.

*b.* Contorted seam of coarse brown sand, with more or less loam.

*c. d.* Brickearth with *Corbicula fluminalis* etc. Bedding obliterated above, clear and undisturbed below.

Turning now to the Uphall Brickyard, just south of Ilford, which I believe has been abandoned for some years, DR. COTTON's account reads thus :—Brickyard "west of Barking lane" [= first of Morris]

	FEET.
Soil with gravel	2
Coarse gravel and sand, stratified	3
Brown, stratified brick-earth	6
Light-brown brick-earth with wavy veins of sand, race and bones	2
Layers of brown and yellow sand, waved; abundance of bones in the upper part	4
Fine yellow and white sand, with freshwater shells	2
Coarse gravel, with water.	

In 1866 MR. S. V. WOOD gave the section shown in fig. 81, which has been reproduced from the original cut.†

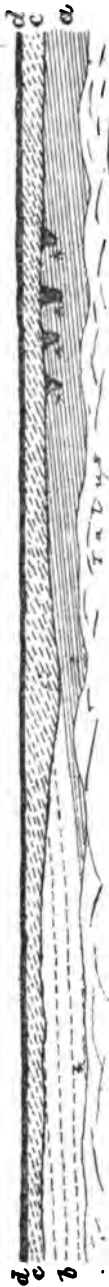
In the following year PROF. DAWKINS described the order of the beds on the southern side of the section, from notes that must have been taken before that year, as follows‡ :—

\* *Geol. Mag.*, vol. iii. p. 59. (1866.)

† *Ibid.*, p. 60.

‡ *Quart. Journ. Geol. Soc.*, vol. xxiii. pp. 92, 93. (1867.)

Figure 81. Section in the Uphall Brickyard, Ilford. (S. V. Wood.)



a. Clayey brick-earth, with freshwater shells.  
 b. Bright yellow sand, with freshwater shells.  
 c. Gravel.  
 d. Warp [? soil].  
 The asterisks to the west (right) show potholes formed by denudation before the deposit of c.  
 The asterisk to the east (left) shows the place whence the remains of *Elephas primigenius*, described in *Geol. Mag.*, vol. i. p. 241, were got.

Soil; 1 to 3 feet.

Irregularly bedded brick-earth and gravel, contorted, the long axes of the pebbles in the main vertical; (about) 6 feet.

Irregular gravel; a foot.

Red and grey sandy loam, with rippled bedding, and with many shells and bones; 4 feet.

Fine sands and brown brick-earths, with layers of shells, and with bones; 6 feet.

Yellow sand and gravel; said to rest on London Clay.

My own notes of this section, taken the same year (1867), differ considerably, giving the following succession, the letters representing the same beds as those in the sections of the London Road brickyard:—

- a. Gravel (? includes the two beds next beneath the soil in PROF. DAWKINS' section).
- b. Brown clay, with bones; 3 feet (but thinning out eastward; where there is a mass of clayey gravelly earth at top); passing down into the next.
- c. Brown and buff loam, and sometimes sand, with shells, pieces of rase and some small pieces of flint; sometimes not clearly divided from the bed below; about 3 feet.
- d. Light-coloured sand, with shells; about 2 to 8 feet seen, the latter eastward, where it was evenly bedded and with layers of loam; in places thin short layers of gravel.

Gravel apparently occurs below.

The last detailed account of this section seems to have come from PROF. J. PHILLIPS, who saw the eastern side under favourable conditions, the manager having had the lower part cleared in his presence, so that he was enabled to record the following details:—

Dark sandy soil, with scattered pebbles; 3 feet.

'Uncallow.' Gravel sand and loam in confused arrangement; 7 feet.

Sandy loam; 2½ feet.

Yellow and ferruginous sand, curved and irregular, with scattered gravel; 4 feet.

Irregular gravel and sand; 4 inches.

Yellow and ferruginous sand and scattered gravel (bones); 3 feet.

Shell-bed. Undisturbed deposit of shells living on the spot; 6 inches.

Laminated clay; a foot.

Pebble-bed in greenish and ferruginous sand (not penetrated).

His shorter section of the southern side is remarkable only as showing the 'Uncallow' to be 10 feet thick at that date.\*

Summing up the various sections, it seems that the Ilford brick-earth is in, rather than under, the gravel (as has been said) for gravel and sand occur beneath it.

Some of the brown clays of these sections are much like London Clay, from which most likely they have been derived. It occurred to me that the reason why the beds at Ilford consist in great part of stiffer clays than those at Grays might be that the former place is in a clay-country (except for the Drift), so that the material is near at hand, whereas the latter place is some way from the clay-tract.

*Between the Ingrebourn and Fobbing Marsh.*

A large sheet of Drift has been mapped northward to Uppminster, Cranham and North Ockendon, whence it is cut off, northward, along the valley of the Mar Dyke. It spreads over fairly high ground, but, on the other hand, reaches down to the marshes of the Thames; and it consists chiefly of gravel, but at Uppminster and Cranham there is much brick-earth.

The London Clay and, in part, underlying beds crop out on the slopes northward and westward of Aveley, the high ground above having a capping of gravel of a higher terrace; and it seems possible that further investigation might extend the clay-outcrop in the valley between this and Uppminster.

We have very few notes of sections in this tract, and none of importance.

At Cranham Hall "in a well at the depth of about 30 feet, bones and shells were found in sand. As many as 20 buckets full might have been collected of the shells. Horns also were found."†

At the gravel-pit, marked on the map, two thirds of a mile S.S.W. of Cranham Church, loam was shown over the gravel.

Just S.W. of Whitepost Farm, North Ockendon, sand was seen.

A thickness of 18 feet of gravel was noted in the pit by the meeting of the three roads N.W. of Aveley.

Crossing the valley of the Mar Dyke, we find that over the higher grounds between Purfleet and Stanford-le-Hope the Tertiary beds are much covered with gravel, whilst the Chalk is mostly bare, indeed almost wholly so at the higher parts. This higher terrace however is mapped as sloping down to the lower one at West and East Tilbury.

In the patch westward of Belmont Castle, between Stifford and West Thurrock, the junction of the gravel with the Thanet Sand is shown in the old pit, marked on the map, S.W. of the house.

Of the small patches northward of Grays good sections are generally to be seen in the large quarries, where the gravel rests in hollows in the Thanet Sand and in the Chalk; but, from the constant cutting-back of the pits, the sections taken at different times vary much. I have a drawing of part of the section in the great pit east of Belmont Castle, made by Prof. T. McK. HUGHES, presumably many years ago, when he was on the Geological Survey, in Kent, which shows a hollow of Drift cutting deeply into the Thanet Sand, and consisting of the following beds, to a total depth of nearly 20 feet:—

Soil, with patches of gravel toward the base.

Irregular wavy beds of brown earth and sand, passing down into grey clayey sand, with, at one part, a layer of brown clay at the base.

False-bedded, coarse, yellow sand, with patches of gravel (chiefly pebbles) at the base.

\* *Geology of Oxford and the Valley of the Thames*, pp. 470, 471. (1871.)

† Dr. J. MITCHELL's MSS., vol. 3, p. 76. In the possession of Prof. PRESTWICH.

My own note of the Drift in this pit was taken in 1872, when there were, at the northern and highest part, hollows of gravel, sand and loam in the Thanet Sand. The largest of these hollows in the northern face of the pit (probably the same as the one noticed by PROF. HUGHES) was very long, and so deep in the middle as to cut through the Thanet Sand to the Chalk. Its contents were being worked for brick-making just north. The next largest hollow, in the western face of the pit (that noted by MR. TYLOR) seems to be let down, with the Thanet Sand, which is "piped" in the Chalk beneath. At the eastern side, touching the road, there was a small hollow of sand and gravel, and also masses of gravel and chalk-rubble mixed up with pipes of the green base-bed of the Thanet Sand.

In 1869 another hollow of Drift was described by Mr. A. TYLOR, whose section, here reproduced by the courtesy of the Council of the Geological Society (fig. 82), would seem to refer to the western side of the great pit.

PROF. MORRIS has drawn attention to the occurrence of blocks of Greywether-sandstone at Grays,\* and said "The sarsen-stones (of which some may be still seen lying about the large chalk-pit), I have noticed during the progress of the workings as occurring on the upper surface of a bed of disturbed chalk, above the solid chalk, and covered by a blackish or carbonaceous clay containing freshwater shells. They are of various sizes, some very large, and more or less waterworn, and may have been originally derived from the boulder-clay [more likely not?] . . . it is probable their position is equivalent to the base of the brick-earth deposits in the adjacent eastern brick-fields."

In the chalk-pit north of the Railway Station, close to the above (? and now joined on to it, under the road) there was, in 1872, on the western side, a shallow hollow of sand on the Chalk, and near by, on the northern side of the pit, another like hollow (of sand and gravel), very likely a continuation of the former, the part between having been cut away: this ended off, on the west, against a thin patch of the base-bed of the Thanet Sand.

Going now to the sheet of gravel over the Tertiary beds, to the east, the pit, marked on the map, at the western corner of Hangman's Wood, a mile north of Little Thurrock, is in finely and evenly bedded gravel, to a depth of 9 feet.

MR. H. W. BRISTOW has supplied the following notes:—

"At the cross-roads at Baker Street, W.S.W. of Orsett, a thickness of 5 feet of red sand and gravel was seen, over loam with gravel."

"At Chadwell, by the north-western corner of the churchyard-wall, there is a little pebbly gravel over ferruginous sand, and the cutting of the lane going south gives a good section, the sand being well and evenly bedded, and underlain by a paler sand, both having small fragments of flint here and there."

"From here to Biggon Heath there are pebbles in the sandy soil of the broad table-land. At the latter place water is said to be plentiful, and the section given by wells was gravel 4 or 5 feet, quicksand 8 or 9 feet."

I have a note of a section, by the edge of the marsh nearly half a mile west of West Tilbury Church, showing brown brick-earth, over light-coloured brick-earth, over Thanet Sand: probably however there may be too little to show on the map.

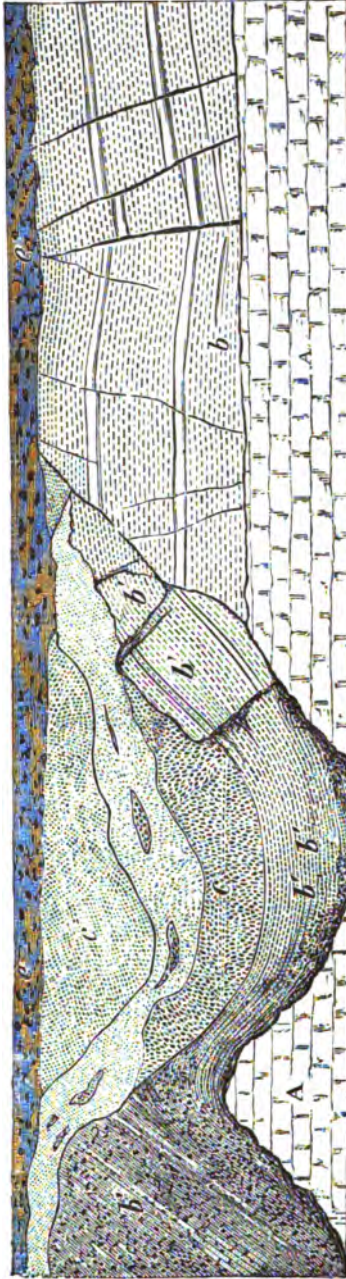
Continuing MR. BRISTOW's notes, "between West Tilbury Church and Low Street much gravel and sand have been got from the large pits, where the deposit consists of yellow sand with layers of small pebbles and angular flints." (I have a note that this sandy gravel is 12 feet thick, and that Thanet Sand is cut into at the bottom, in the pit just W. of Low Street).

"By the road just north-west of the "Rookery" (Mucking Ford), I noticed coarse gravel, made up of fair-sized pebbles and white-coated Chalk flints, different from the gravel on the hill-tops."

"To the north, at Sutton's Farm, a well passed through 4 or 5 feet of gravel and 30 or 40 feet of bluish sand (Eocene), and another, at Wharton Hall, through 3 or 4 feet of gravel and 8 or 9 feet of bluish quicksand."

\* *Geol. Mag.*, vol. iv. pp. 63, 64. (1867.)

Figure 82. Section at the Western Face of the Great Chalk Pit, Grays. (A. TYLOR.)\*



Scale 25 feet to an inch.

- e. p soil. "Covering bed" of Mr. TYLOR.
- c. Gravel series, 5 or 6 feet thick over the undisturbed Thanet Sand on the north, 30 feet thick in the middle of the hollow.
- b'. Thanet Sand that has sunk into the hollow [that on the south seems to be reconstructed]. The fissures in the sand filled by veins of gravel, up to 1½ inches wide. In the middle part masses of the sand are shown falling into the hollow.
- b. Thanet Sand in place; 25 feet.
- A. Chalk. The pipe reached 25 feet down into this.

\* *Quart. Journ. Geol. Soc.*, vol. xxv., fig. 31, pp. 96, 97.



"At Mucking about 10 feet of gravel may be seen in the railway-cutting and in the pit by the crossing. It is fine, sandy and ferruginous, with occasional layers of sand; rarely an unaltered white-coated chalk-flint may be noticed. There are also old pits east of the railway."

"In an old overgrown pit on the road from Stanford to Stanford Marsh the gravel seems to be 10 or 12 feet thick, and the bottom of the pit is apparently cut down to a light-grey sand" (? Eocene).

"South-east of the farm-buildings, south of the Thames Haven Branch Railway and near the Marsh, were pits showing 6 or 8 feet of gravel, finely bedded with layers of sand, and mostly made up of pebbles and small angular fragments of flint."

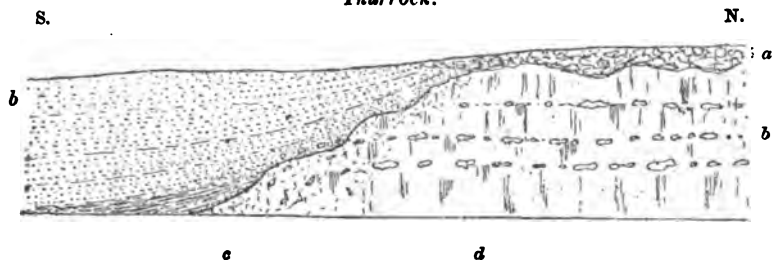
"The gravel in a pit behind Eastwood, east of Stanford, is fine, and at Corringham also, where a good deal has been dug in pits between the church and Henley's, and where it is composed of small pebbles and angular fragments of flint interbedded with much yellow sand. There are other pits at Herods" (? Herods).

Returning to the higher ground, where, between Orsett and Mucking, there is a large separate patch of gravel, Mr. BRISTOW says, "at Mucking Heath the gravel is from 8 to 10 feet or more thick, and a red sand is said to occur to a depth of 40 or 50 feet. Just to the west a pit in the copse north of Sibbery Hall showed 12 feet of ferruginous sandy gravel, angular and pebbly, with continuous and lenticular layers of ferruginous sand obliquely laminated."

Dividing the Chalk slope from the marshes, from High House, east of Purfleet, to Little Thurrock, is a narrow strip of River Drift, which nevertheless is of greater interest than the broad tract just described; for not only is the Drift here much thicker as a rule, but it is sometimes steeply banked against the old Chalk cliff, and it is of more varied character, including the well-known fossiliferous beds of Grays.

A new chalk-pit and its approaches south of Mill Wood and West Thurrock, on the western side of the road (Millwood Lane) up the hill, gave a good junction-section of the Brick-earth beds and the chalk, as in fig. 83. (1872.)

Figure 83.—Section at the Entrance of a Chalk Pit between Grays and West Thurrock.



- a. Irregular gravelly soil (the chalk decomposed 3 or 4 feet down).
- b. Bedded sand with loam; over 15 feet.
- c. Rubbly chalk at the junction.
- d. Chalk with flints.

The pit itself is in Chalk, but where it narrows, to the cutting for the tramway, bedded sand comes on suddenly, and further south the lower part of this is clayey and like the Grays brick-earth.

Another pit, for the Lion Cement Works, close by on the other side of the lane, showed a like abrupt rise of the Chalk from beneath sand etc.; but here the Chalk is covered for a little way north by a very calcareous irregular sandy gravel or gravelly sand. To the south, along the tramway, there was at first little but sand; then gravel and sand over loam and clay, sometimes with

sand beneath; and still further, before getting to the road, gravel and sand only. South of the road again there was sand and loam, with gravelly layers, beneath a little gravel; and then gravel only.

A third of a mile further east, and southward of Belmont Castle, another pit again showed at its entrance a thick mass of sand ending off abruptly against the Chalk; whilst some way south the section in the approach was earthy gravel, over sand and clay, over sand.

When the Drift here was mapped no one would have thought of drawing its boundary so high up the slope, in the absence of sections, and that line was then drawn, by feature, at a lower level, where one expected the Drift to end off.

MR. BRISTOW notes that at Grays "the wells between the railway and the high road are sunk in a light-coloured ferruginous clayey sand, for a depth of 10 feet or so, with gravel beneath."

The great brickyards from Grays to Little Thurrock are now things of the past; but the fine sections shown in them have been recorded at various times, and have been seen by many geologists.

The first detailed description of the River Drift of Grays was from the pen of the late PROF. MORRIS,\* from whose paper the following remarks are taken:—"The deposit, which extends east and west, and about a quarter of a mile in width, fills up a valley between two ridges of irregular height; that to the north being part of a long range of chalk hills . . . and that to the south consisting of rubbly chalk with irregularly disposed flints, about 30 feet high . . ."

"The deposit being worked in three different pits, an opportunity is afforded of examining its stratification for more than half a mile. The section of the . . . western pit, at the south side, is" as follows:—

Mould; 3 feet.

Loam and sandy clay, with few plants [? flints] and chalk pebbles; 10 feet.

Rounded and angular pieces of chalk, flints, quartz, sandstone, etc., fine sand, and fragments of shells; to 4 feet.

"On the north side occur":—

Loam and sand; 18 feet.

Ferruginous sand, with angular flints and chalk-pebbles, with many unworn freshwater and land shells, fragments of bone, vertebra and tooth of fish; 2 feet.

Loam and sandy clay; 4 feet.

Beds said to extend 15 feet deeper, to chalk.

"In the second pit is the following section." It was from this pit that the great number of Mammalian remains came:—

Black mould, and burnt brick-earth; 3 feet.

Loam and reddish sand, with flints; the lower part waved and irregular; 5 feet.

Iron-sand, red and yellow, with horizontal patches of white; 12 feet.

Brown sandy clay; 10 feet.

Two beds of shells (as before); 2 feet.

Lignite, reeds, leaves, blue clay, with mica, the upper part with numbers of shells of *Unio* and *Anodon*; 15 feet.

Gravel and sand said to occur below, then

"Bull's head" or iron flint bed, and then chalk.

"In the third, or eastern, brick-field, the upper beds thin off, the brown sandy clay coming within 7 ft. of the surface, and is worked to the depth of 15 ft.: the lower part contains numerous fragments of shells, with some layers of more perfect ones. Still further to the east the whole of the beds thin off, and, apparently, disappear beneath the marsh." . . .

\* *Mag. Nat. Hist.*, vol. ix. pp. 261-264. (1836.)

"The strata have a general inclination of 15° to the north [? false-bedding]. The layers of the loam and sandy clay appear to be made up of small flat fragments of shells, arranged parallel to each layer, the laminae varying from eighteen to twenty in number in the thickness of an inch. The sandy beds present an appearance of false stratification: and it is not uncommon to find horizontal alternating with wavy and transverse layers. The shells are irregularly distributed: some genera are more abundant at one spot than another. The lignite is also variable in its position, sometimes dividing the shelly beds, and at others occurring below them."

In 1867 the same author noticed that the brick-earth was almost worked out and remarked that "the general section of these pits may be divided into two series, the lower, or fossiliferous zone, comprising the gravel and overlying brick-earth, in which both the mammalian and molluscan fauna occurred, and the upper or unfossiliferous zone, comprising the false-bedded sands and brown clays from which to my knowledge no fossil remains have been obtained."

In the opinion that "the false-bedded character of the upper sands affords evidence of a constant change . . . in the direction of the currents"\* there may be some mistake, as it seemed to me that the false-bedding was all in one direction, or down the river. Moreover, according to my notes, which must have been taken somewhere about this time, fossils will be seen to occur in what I should be inclined to call the upper part of the deposit. These notes seem to be about the next chronologically, and they are backed by a section noted by PROF. HUGHES, to much the same effect, and taken probably at no great distance of time; they are in the form of a general section, as follows:—

	FEET.
Soil - - - - -	
Brownish-red clayey sand and sandy clay, with flints (rainwash ? the "trail" of the Rev. O. Fisher) - - - - -	5
Valley Drift, 35 feet or more. { Light-coloured sand; the upper part more evenly bedded, the lower part with oblique current-bedding (the lines of current-bedding being inclined eastward, that is down the valley); with a few flints and lenticular masses of gravel. Two feet above the bottom there is sometimes a six-inch bed of stiff brown clay. Sometimes there is gravel at the bottom; sometimes a 15 or 18 inch bed of bright ferruginous sand, crowded with shells, sometimes passing into the bed below - - - - -	about 20
{ Grey clay, finely laminated by partings of sand, the bottom part more sandy; with shells and bits of wood. Sometimes a bed of whitish gritty sand with shells about 8 feet from the top. Bones have been found low down in this bed - - - - -	about 12 to 15
{ Gravel, with pebbles of granite (not seen, but on the authority of Prof. Morris) - - - - -	3 to 4
Chalk.	

In 1867 PROF. DAWKINS also published a section "at Mr. Pearson's Pit"† which differs in some details, making the soil and the sandy contorted "trail" from 6 to 7 feet; the false-bedded sand, etc. only 10 feet; the laminated clays, with seams of sand and of gravel, and with a lenticular mass of shells 4 feet down, as much as 18 feet; and the sand and gravel, with shells, next above the Chalk 10 feet.

Two years later Mr. A. TYLOR gave a section at a spot on the eastern side of one brickyard, by a road that divided it from another, in which he makes the false-bedded sands (accidentally called "muds" in one part) 18 feet thick, with 4 feet of shelly pebbly gravel beneath.‡

\* *Geol. Mag.*, vol. iv. p. 64.

† *Quart. Journ. Geol. Soc.*, vol. xxiii. pp. 94, 95.

‡ *Ibid.*, vol. xxv. p. 84. (1869.)

*East Essex, between the Thames and the Crouch.*

Below Fobbing not only is there no high terrace gravel on the northern side of the Thames, for miles; but also the lower terrace has been cut away by the river and its creeks, so that the marshes are bordered by London Clay. At Leigh, where the marsh ends and the tidal water reaches up to the cliff-foot, gravel caps the high ground, and at Southend the River Drift comes on in mass, at a lower level, ranging irregularly northward to a little beyond Rochford, whence its boundary turns eastward. In this tract brick-earth is predominant at the surface. The higher gravel seems to slope down eastward to the rest; but in some parts there are detached masses.

Mr. BRISTOW has contributed the two following paragraphs:—

"Beyond the western edge of the Southend gravel the London Clay of the cliff is bare, until near the hedge running to Marina Villa, where there is a small hollow, extending to the road, with a thin deposit of brick-earth, which reappears and forms the upper part of the cliff at the fence from the road to Snella. This brick-earth is on the whole homogeneous, sandy, and of a pale colour, the upper part browner and more clayey; it rests on a fairly even surface of the London Clay, and is at least 6 or 8 feet thick. Here and there is a thin layer of gravel at the surface of the ground, but not in sufficient quantity to be mapped."

"The upper part of the cliff at Southend is of gravel, made up of angular fragments and pebbles of flint, with sand and layers of clay, to a thickness of at least 12 feet. The gravel consists sometimes of very small angular fragments only, and the sand is sometimes ferruginous, sometimes almost white."

At the top of the cliff, about a third of a mile westward of the pier there is a hollow of somewhat peculiar brick-earth, with what may be the remains of an old land-surface, a peaty clay, in the middle, the succession of beds being as follows (noted August 1887):—

		FEET.
River Drift	Brown loam, with a gravelly base . . . .	3 or 4
	Grey sandy loam . . . . .	1 to 1½
	Buff and brown sand and clayey sand . . . .	about 4
	Blackish clay . . . . .	½ to 1
	Grey loam, partly gravelly (small stones), passing down into sand, and with no marked division from the next below . . . . .	6 or more
	Light-coloured, slightly iron-stained sand, sometimes gravel . . . . .	4?
	Brown London Clay.	

The top two beds may represent the brown and grey brick-earth that covers so much space northward.

MR. BRISTOW again notes that "a good deal of gravel has been worked out at Southend on the southern side of the high road east of Brickhouse [Porters of the new map] where it consisted chiefly of small flint-pebbles and angular and subangular flints, somewhat sparingly disseminated in a sandy base, and with layers of sand; the whole of a dark ferruginous brown, but here and there the iron-oxide being in such quantity as to give a black appearance, the stones having a black shining coat. A thickness of 10 or 12 feet was shown."

Going northward from Southend, the cutting north of the Great Eastern Railway Station was not finished at the time of my visit, in August 1887. At the southern part the loam only was seen; but to the north, where the line cuts through a hedge, rather more than half way to Prittlewell, the base of this was seen, the gravel beneath being touched. The junction dipped slightly south; the top 3 or 4 feet of the loam was seen to be brown, whilst the rest, to a depth of 8 feet, was light-coloured (buff) and more sandy, the bottom 3 feet being damp.

At the Prittlewell road the gravel rises up, and beyond it is bare of loam, except for some very small patches. Both gravel and sand occur, and the cutting eastward of the Priory gave a good section of these, which were somewhat irregularly bedded, and partly false bedded. This section made a slight extension of the gravel-boundary needful.

In the next cutting, about a mile north of Prittlewell, the loam was seen along the base.

The shallow cutting southward of Rochford was soiled over; but sand was seen at the base in places (so that the loam is probably cut through) except at the southern end, west of Three Ashes, where the loam goes to the bottom.

Of the patch of gravel, that rises up from beneath the brick-earth, to the west, near Eastwood, Mr. BRISTOW notes that "in the road-cutting just S.W. of Nobles Green brown London Clay was well seen, underlying the sandy gravel of the hill-top, and by the roadside about a quarter of a mile east of that place gravel, 4 or 5 feet thick, again rests on brown clay."

A little north-westward of Rochford Station the ditch, by the side of the railway, showed (in 1887) a little loam over gravel, and in two temporary ditches, across the line (a little north of the lane) the gravel was cut through, to the London Clay.

The long shallow railway-cutting that runs to about a mile north-westward of Rochford was unfortunately soiled over at the time of my visit, in August 1887, and no previous observer seems to have noted the beds shown. All that could be seen was along the base, for a depth of but a few inches, and this proved the presence of brown and grey clay and loam, which, without further evidence, one would have hesitated to classify. At one spot however, about a quarter of a mile N.W. of the farm called Swaines, for the length of about a foot, a white mass occurred, which proved to be composed of shells, chiefly *Corbicula fluminalis*; from which it is clear that there is here some of the shelly brick-earth of the old Thames, like that of Grays and Erith. That brick-earth had not been mapped here originally, in the absence of any section, was to be expected, and the extension that I made becomes of uncertain boundary directly after leaving the railway (eastward). This find of course tends to show that we are here dealing with old Thames Drift, and not with a totally independent set of beds, as has been suggested (see p. 364).

Farther openings in this interesting fossiliferous brick-earth should be looked for, and it is to be hoped that geological members of the Essex Field Club will note any that may occur.

Turning to the easterly extension (chiefly in Sheet 2 of the Map) Mr. H. B. WOODWARD notes that "the best section of the gravel is on the coast westward of Shoebury Ness, where the cliff shows up to 18 or 20 feet of false-bedded gravel and sand," beneath which the London Clay comes out. "Gravel was again seen in trenches at Shoebury Ness, and it passes irregularly under the brick-earth." The composition of this gravel is given further on, with that of Burnham (p. 423).

Mr. WOODWARD continues:—"In the small patch of gravel at Pigsgate, E. of Southchurch, there was a pit 8 feet deep, and at Southchurch Wick another patch, 2 or 3 feet thick, has been worked in places."

Of the brick-earth he says "this deposit was best seen in the large brickyards at Shoebury, where brown loam, from 6 to 8 feet thick, rests sometimes on gravel or sand, at others on London Clay."

"About the year 1840 a brickyard was open by the coast west of Shoebury, half a mile or so S.W. of Thorpe Hall, and *Cyrena* [*Corbicula fluminalis*] is said to have been found by PROF. PRESTWICH."

"In the pits S.E. of North Shoebury gravel and sand have been reached at a depth of 6 or 7 feet. At Kings, near the shore, the section seen was 2 or 3 feet of brick-earth, over 3 feet of false-bedded sand, with layers of gravel."

"Brick-earth was worked near the Brewery at Great Stambridge, E. of Rochford."

"At Sams, W.S.W. of Paglesham, is a detached mass of gravel and sand, 3 to 4 feet thick, and about the same thickness was worked in the smaller patch, at Ballans Gore, to the north, where also there is a little brick-earth."

"N.W. of Paglesham, near Canewdon Wick, Lionhouse, and Loftmans, the gravel is again 3 or 4 feet thick and has been worked."

MR. F. J. BENNETT notes that "just north of the kiln, about half a mile S.W. of Paglesham, in the same field and at the same level, there were, in 1871, two pits, the one showing 3 feet of gravel over a foot of sand, and the other 5 feet of brick-earth."

*East Essex, between the Crouch and the Blackwater.*

The River Drift of the old Thames occurs here mostly in detached masses, capping the hills that border the marshes; but in some cases brick-earth occurs at a lower level.

MR. WOODWARD says, of this and the foregoing tract, "the gravel which occurs in patches from Shoebury Ness to Bradwell is of a uniform composition. The following percentages were taken by MR. BENNETT and by myself."

Materials of stones.	Burnham.	Between Southend and Shoebury Cliff.
Flint, angular and broken	15	20
" rolled -	32	28
" subangular -	44	30
" entire -	—	3
Quartz -	8	5
Chert of the Kentish Rag	6	14

MR. W. T. FOXLEE, the Resident Engineer of the Essex Lines (Great Eastern Railway), has sent me some sections, based on 12 trial-holes, made in a field by the railway, south-westward of St. Mary's Church, Burnham, which give the following general section:—

Soil; from a foot to 3 feet.

Clay and stones; mostly from a foot to 4 feet, but absent at two spots, where the gravel rises up.

Sand, not always present; up to 3½ feet.

Gravel, up to 7 feet proved.

Continuing Mr. Woodward's notes:—"At Burnham the gravel was largely worked on the eastern side of the high road between that place and Southminster. On the western side it is thinner, and ends off in patches, so that is very difficult to fix a boundary between it and the London Clay."

"East of Burnham there is brick-earth; but it had not been worked."

PROF. DAWKINS has left the following note of a pit at Burnham:—

Pebbly wash; 3 feet.

Clayey gravel; a foot to 5 feet.

Fine sandy pebbly gravel, with a few pebbles of white quartz; 5 feet.

Fine yellow sand; over 3 feet.

MR. W. T. FOXLEE has also given me an account of 12 trial-holes, made in a field on the western side of the railway just south of Southminster Station, from which the following general section has been made:—

Soil; a foot in most of the holes, but up to 4½ feet.

Clay and stones (in 8 holes); 1½ to 2½ feet. Clay in 1 hole; 4 feet.

Clay and gravel (in 2 holes); 1½ and 3 feet.

Gravel (in 10 holes); 3¼ to 6½ feet.

Sand (in 2 holes); 2 and 2½ feet.

Sand and small stones (in 2 holes); 3½ and 4½ feet.

A section along the centre-line of the railway, from northward of the brook to Hall Road, sent by the same gentleman, shows that the level of the top of the "ballast" (gravel) varies considerably.

MR. BENNETT notes that "near Northwick, eastward of Southminster, a thickness of 8 feet of gravel was seen, and at Landwick, eastward of Dengie, one of 10 feet."

"At the small outlier of Hide House, westward of Tillingham, gravel was seen to the depth of 7 feet, and there were good sections at the patch at Curry's Mill, between Tillingham and Bradwell."

PROF. DAWKINS noted the following section by the Queen's Head, Bradwell :—

Brick-earth ; from a foot to 10 feet, irregularly on :—

Red sandy irregular flint gravel ; 10 to 12 feet.

It may be a question whether this patch, reaching down to the marsh of the Blackwater, may not belong to that river rather than to the Thames.

## CHAPTER 24. RIVER DRIFT.

## VALLEY OF THE THAMES, SURREY AND KENT.

*Between the Mole and the Wandle.*

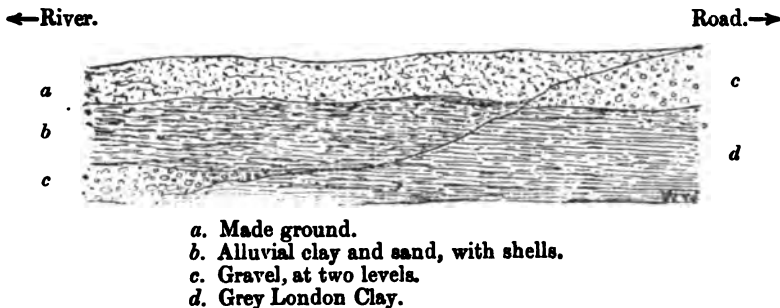
FROM Thames Ditton to Petersham the right side of the river is bordered by gravel, with a breadth varying from about a third of a mile to more than  $1\frac{1}{2}$  miles. At the southern end of Richmond a cliff of London Clay comes down to the river; and thence there is again a gravel-tract from Richmond to Wandsworth.

There are also large remains of a high terrace on the high grounds of Richmond Park, Kingston Hill, Putney Heath, and Wimbledon. Though on the south this older gravel is almost flat, on the north there is a tendency to slope down towards the river, so that the smaller northern patches are at a lower level than the rest.

Of this high gravel the composition was noted as chiefly subangular flints, with flint pebbles, and layers of coarse gritty sand, the best sections being at Kingston Hill and by Combe Wood.

The Waterworks on the right bank of the Thames at Ditton have given sections of the alluvium and gravel, from one of which fig. 84 was taken.

Figure 84. Section at Part of the Filter-beds of the Lambeth Waterworks, Thames Ditton, 1867.



MR. SEATON, the resident engineer, got some cannon-balls, gun-barrels, spear-heads and pottery from the alluvium; an elephant-molar from the higher gravel; and various fossils and a large piece of "Highgate Resin" from the London Clay.

PROF. PRESTWICH has recorded the finding of elephant-remains in the gravel near Kingston.\*

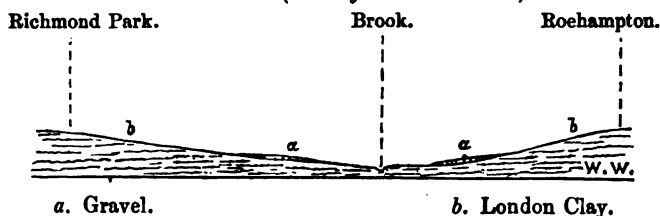
The boundary of the gravel-flat of Ham and Petersham seems to be almost exactly the same as that of Richmond Park, within which the London Clay rises up sharply to some height above the flat. Some slight signs of low terraces may be seen at the northern part of the tract. At Ham Common there is at one part a little brick-earth, at another a little sand, and at Petersham much of the latter above the gravel; whilst near the river there is chiefly gravel only.

\* *Quart. Journ. Geol. Soc.*, vol. xii. p. 132. (1856.)



A little south of Richmond Bridge gravel again comes on, and seems to spread over all the lower part of the town, whence the boundary-line runs eastward to Wandsworth. The only change from the easterly course is south of East Sheen, where the gravel has once run some way up the brook-valley, although the brook has since worn its way through to the London Clay, down to within a quarter of a mile of the high road, leaving a spur of gravel on either side, beyond which the London Clay hills rise up, as shown in the section, fig. 85 (along a line a mile and a half long, and nearly E. and W.; the vertical scale exaggerated).

Figure 85. Section from the Northern Part of Roehampton to Richmond Park (south of Sheen Common).



In Kew Gardens there is gravel, and in parts sand above it, and the latter is shown along the lane S.E. of the village. The following section was noted at Kew many years ago\* :—

Mould;  $1\frac{1}{2}$  feet.

[River] { Reddish, sandy clay; 5 feet.

[Drift] { Gravel; 8 feet.

{ Reddish sand; with remains of elephant.

[London] Clay.

At East Sheen, Barnes Common, and Putney there are sections of the gravel, which is cut through to the London Clay in the railway-cutting east of the last place. Between the railways at Barnes there is sand and a little brick-earth over the gravel.

At East Sheen rises a fairly-marked terrace (the third), which however I have not traced for any distance; but I have traced the rise of a lower one (the second) from the river at Barnes, between the village and the railway, to the brook (S.E.), and thence eastward, on the southern side of the brook, to the river at Putney. The lowest terrace therefore here takes up the space in the bend of the river, as on the other side in the bend next to the west (see p. 398).

#### *Between the Wandle and Woolwich.*

On the east of the Wandle there is some difficulty in distinguishing the gravel of that river from that of the Thames, the two gravels joining. Whilst however the lower flat, next the Wandle, must belong to that stream, the higher mass of Wandsworth Common belongs to the Thames, though it seems to join on to gravel belonging to a branch of the Wandle, on the south.

Besides this the only isolated high patches are at Clapham and at Balham, besides the still higher ones of Lower and Upper Norwood, as to the classification of which there may be some doubt, especially with the highest and most southern.

Whilst from Upper Tooting southward the gravel is never half a mile wide, it broadens to nearly a mile at Wandsworth Common, where it forms the highest ground. It was at first thought that this gravel joined on to the lower terrace to the north, and it was not until fresh sections were seen that one was enabled to trace (on the skeleton six-inch map) the narrow outcrop of London Clay that separates the two. By this the northern end of this high terrace is

\* G. CUVIER. *Phil. Mag.*, vol. xxvi. p. 302. (1807.)

very well marked, forming the rising ground from the south of Wandsworth railway-station north-eastward across the railway to the junction with the other line.

One is inclined to differ from PROF. PRESTWICH when he says that "the gravels on Clapham, Wandsworth, and Wimbledon Commons are . . . on the same plane";\* the first two are, without doubt; but the last seems on a higher plane. PROF. PRESTWICH indeed writes to me that he himself might differ from the above now.

The relations of some of these gravels are shown by fig. 86, which has been redrawn from the original (made many years ago) by MR. J. G. GOODCHILD, so as to have the advantage of the levels of the new Ordnance Map.

The railway-cuttings through Wandsworth Common show both the gravel and the underlying clay; the junction is very uneven and irregular in that of the Crystal Palace line, so much so indeed that the clay is often almost at the surface, though a few yards off it is covered by many feet of gravel.

PROF. T. R. JONES favoured me, some years ago, with the following notes on the gravel of Wandsworth Common.

"The pits showed about ten feet of gravel, with the largest stones towards the bottom, and irregular masses of peat in the uppermost six feet, in which upper part the bedding was much disturbed, whilst it was not in the lower part. At a pit near the bridge at the bottom of Nightingale Lane, between the gravel and the London Clay was some black fetid clay with bones of horse &c., and with phosphate of iron" [vivianite].

The gravel of Wandsworth Common is separated from that of Clapham Common, which belongs to the same terrace, by the valley of the little brook that flows into the Thames at Battersea, which is cut through to the London Clay as far north as the railway.

As at Wandsworth Common so also at Clapham, this terrace is divided from the lower one to the north, or from the alluvium, by a narrow outcrop of London Clay.

TO PROF. T. R. JONES I owe (1866) this note of a gravel-pit in building-ground in Victoria Road, Clapham Common (joining the Wandsworth Road):

Gravel and sand, irregularly bedded, 14 feet. The stones from the gravel were quartz, micaceous sandstone, greywether-sandstone, Lower Greensand chert and sandstone, a London Clay nodule, flints large and small, and a few flint-pebbles: At the bottom unrolled flints, boulders of sandstone, lumps of Tertiary shell-rock and casts of *Cyrena* in red clay.

London Clay, with a waved surface.

It must have been close by this that I saw, some years earlier, pits, in sandy gravel, bedded and false-bedded; the like being also shown in the cuttings of the London Chatham and Dover Railway.

The works of the Southern High-level Sewer were of use in settling the north-eastern boundary of the Clapham gravel; for whilst at the Plough Inn, and thence for some way towards Stockwell, gravel was found, further in that direction, near the fourth milestone (from London Bridge?) the London Clay was found at the surface.

Turning now to the lower terrace, there is an unbroken sheet of gravel, with occasional cappings of brick-earth, from Wandsworth to Deptford, cut through however at the surface by the alluvium north of Clapham, and with a fairly even boundary, except for the bay up the Effra Valley, at Brixton. It is but slightly separated from the northern edge of the terrace above described: thence the boundary runs along the foot of the London Clay hills, to Camberwell, and thence nearly along the high road to Deptford.

I cannot say that all the space between this line and the river belongs to one terrace; indeed, Battersea Park seems to form a still lower one, and there are signs of the same in the thickly-built districts north of Camberwell.

\* The Ground Beneath Us . . . p. 31. (1957.)

Figure 86. Section across the Valley of the Wandle, from Wimbledon to Streatham Common.



Horizontal scale an inch to a mile. Vertical scale four times as large (an inch to 1,320 feet).

+ Ordnance Datum.

- a. Alluvium of the Wandle.
- b. Gravel. Part belonging to the Wandle, part joining on to the terrace of Wandsworth Common, part belonging to the higher level of Wimbledon.
- c. Bagshot Sand (Wimbledon).
- d. London Clay.

Beyond the Ravensbourne gravel occurs only for about two miles, along the foot of the Greenwich hills.

In a hole dug 50 or 60 yards south of the railway, on a road E. of Wandsworth (presumably Usk Road), I saw, in 1861, about 20 feet of buff sand, with here and there a few small flints and pebbles, and this is a little way up the slope of the hill.

Southward and eastward of Battersea there is much brick-earth, which has been worked.

In 1873 Mr. J. A. COOMBS\* described a new section that "was exposed on a piece of ground recently acquired by the London Gas-Light Company for a Gas-holder Station . . . to the north of the Prince of Wales' Road Battersea, between the . . . London, Brighton, and South-Coast, and the London, Chatham, and Dover Railways, near the point of their separation . . . The total length of the excavation . . . was about 400 feet, by about 200 feet in width, and 30 feet in depth, the direction of the longest distance being very nearly from N.W. to S.E." (fig. 87, p. 430).

"The average surface of the ground was 12 ft. 9 in. above the Ordnance Datum . . . The general Section was as follows":—

Rubbish, Mould, and Alluvial Soil	-	2 feet.
Gravel [and sand]	-	22 "
Altered London Clay (brown)	-	1 "
London Clay	-	5 "

"The thicknesses are merely averages, as in many places pot holes occurred in the London Clay, which would add at least 3 ft. to the thickness of the gravel given above." The "Gravel consisted of intercalated bands of sand and ballast of varying degrees of coarseness."

The stones, in some layers of the gravel, were for some distance, "covered with a black, and, when freshly exposed, unctuous material, which Mr. W. H. Hudleston . . . has shewn to be . . . oxide of manganese. In some cases, layers of this black gravel, after extending for some distance as one band, were suddenly divided, and continued . . . as two layers separated by a foot or more of . . . gravel. None of these layers exceeded . . . six inches in thickness, and in general the thickness was not more than two or three inches."

"Towards the north-west portion of the excavation [or where Alluvium is coloured on the map], and about 8 feet above the London Clay, was a deposit of blueish-black sandy, or rather muddy, clay, containing layers of subangular pebbles, and frequently intersected with vertical rootlets of plants . . . This deposit thinned out from . . . 5 feet at the limit of the excavation to nearly the centre of one of the tanks [fig. 87] . . . The peculiar feature of this deposit was that it was covered by, as well as rested upon, . . . gravel [but was the overlying gravel in place?] . . . This Black Gravel had every appearance of a . . . freshwater deposit, but was apparently destitute of the fluviatile shells usually found in river accumulations."

"Mammalian remains were obtained from the Valley Gravel," and part of the paddle-bone of a *Phiosaurus*, "probably derived from the Kimeridge Clay," was also found.

Along the course of the great sewer between North Brixton and Camberwell much gravel was found, and much water also, 20 feet of gravel and sand having been dug through in places, without touching the London Clay.

Mr. S. R. PARRISON noted, in 1863, that "the low-level sewer now in course of construction at Deptford is excavated between the creek and the main street, in a deep bed of gravel" and that "Fragments of elephant's tooth, and a whole tooth of rhinoceros (P)" were found.†

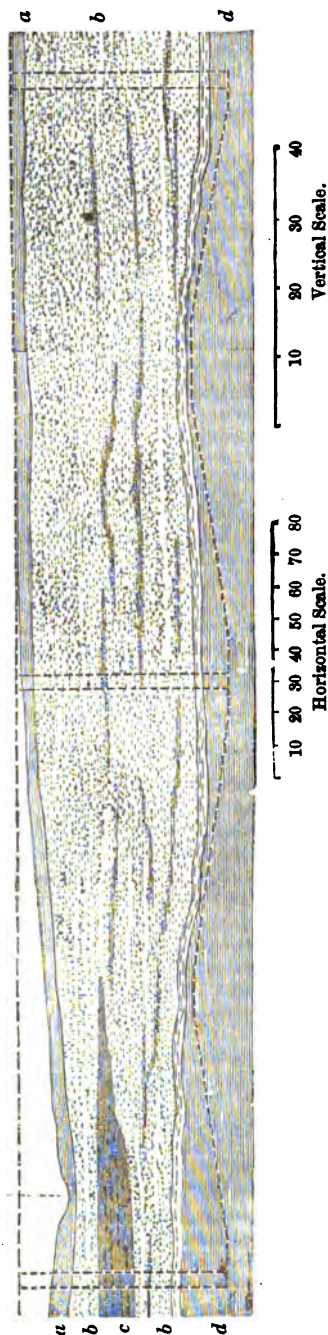
There is a small patch of a higher terrace south of Deptford, just north-westward of Loam Pit Hill, the northern boundary of which seemed rather doubtful.

At some new houses a little south of Greenwich old railway-station I saw 15 feet of brown sandy gravel nearly all of pebbles.

\* *Proc. Geol. Assoc.*, vol. iii., no. 1, pp. 33-35.

† *Geologist*, vol. vi. p. 234.

Figure 87. Section at the London Gas Light Company's Premises, Battersea. (J. A. COOMBS.)



- a. Soil &c.
- b. Gravel and sand.
- c. Black clay (up to 5 feet), in the gravel.
- d. London Clay (discoloured at top).

The broken line across d (London Clay) shows the base of the excavation, which was not carried far down into that clay.

This figure has been kindly lent by the Council of the Geologists' Association.

In 1887 MR. GOODCHILD noted ochreous loam, full of flint-pebbles, on the other railway between Brand Street and Prior Street, and again, to a depth of 25 feet, a little eastward of Prior Street.

"About a hundred yards from the river at Greenwich, and about thirty-three feet from the surface, the workmen engaged in some sewage operations, a few months back, exhumed from a coarse gravel a considerable number of mammalian remains . . . The bones were remarkably well preserved . . . they included horn-cores, teeth, vertebræ, and other bones of several individuals of the Urus (*Bos primigenius*), vertebræ of Horse . . . ; bones of Rhinoceros . . . Hippopotamus, and of two or three species of Cervus."\*

The railway-cutting eastward of Maze Hill Station showed sand with pebbly gravel, irregularly overlying the Thanet Sand, on the western side of Green Lane, and occurring also a little eastward. Further east, by the south-eastern part of the Royal Hospital Cemetery, gravel and sand were again seen over the Thanet Sand, but the Drift only crosses to the southern side of the line at one spot, and it leaves the northern side nearly opposite the middle part of the cemetery.

In the Cemetery the graves are in brown pebbly gravel at the eastern side, chalk being touched eight feet down at the highest part (southern end) whilst lower down there is sand beneath the gravel.

Along the eastern and lower part of the great chalk-pit near Charlton railway-station there was (in 1870) a mass of brown false-bedded sand, with pebbles and broken shells (from the Woolwich Beds) over the Thanet Sand.

### *Between Woolwich and the Cray.*

From Woolwich to near Erith the Lower London Tertiaries rise up at once from the marshes, without any border of gravel, unless any of the pebbly mass mapped as Blackheath Beds, north of the fault, should turn out to be resorted.

From Erith to Crayford the gravel of the lower ground is bordered by a thick mass of fossiliferous brick-earth, rising to a higher level, and at Crayford there are some remains of a higher terrace of gravel.

The deposit of brick-earth up the little side-valley of East Wickham seems to belong rather to a small bay of the Thames than to any tributary, which could have been but very short, whilst the brick-earth is thick. It was first described by PROF. MORRIS, as "consisting of brick earth, sand, and gravel, 25 feet thick, and containing remains of the horse, ox, and deer."†

PROF. DAWKINS said, in 1867, "The section now exposed presents 50 feet of chocolate-coloured loams, devoid of shells and bones, but highly charged with snow-white crystals of carbonate of lime, which form ramifications in every direction. The layer of sand and gravel, whence the remains . . . were obtained, is now worked out."‡ One is disposed to think that the thickness here assigned may be excessive.

When the Geological Survey was originally made the following section was noted at Wickham Lane Brickyard, as given by a shaft, sunk to get chalk :—

Brick-earth, fully 30 feet (taking into account that cut away at top).

Gravel, 3 or 4 feet.

Sand [P Thanet].

Chalk, touched about 70 feet down.

The brick-earth seen was brown, bedded, and with a little sand in parts. The bones found here were said to come from between this and the gravel, and the gravel was sometimes but a few inches and sometimes 9 feet thick.

\* G. S. BOULGER, *Proc. W. Lond. Sci. Assoc.*, vol. i. pt. ii. p. 47. (1876.)

† *Mag. Nat. Hist.* ser. 2, vol. ii. p. 540. (1838.)

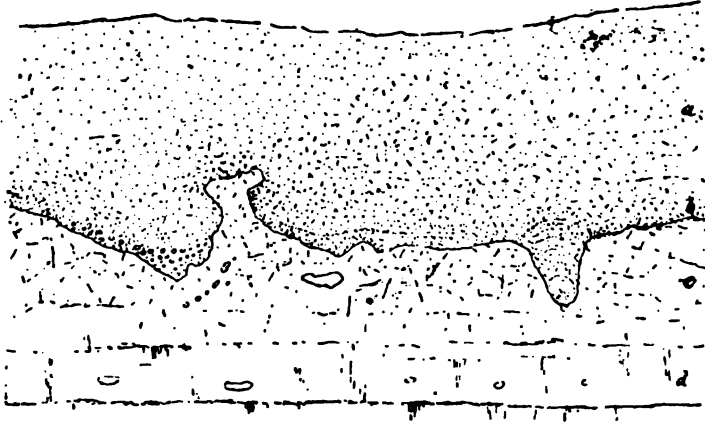
‡ *Quart. Journ. Geol. Soc.*, vol. xxiii. pp. 98, 99.

A dip of from  $7^{\circ}$  to  $14^{\circ}$  down the side of the valley (eastward) was noticed, and a smaller one southward; but at one place these dips were reversed.

Of late years the pits here have been much extended, showing good sections of the underlying beds, and of their abrupt junction with the brick-earth (see p. 144). The fossils got here do not approach those of Erith, etc. in number or in variety.

My colleague MR. GOODCHILD has given me a drawing of the junction of the brickearth and the Chalk in a pit at Old Park Wood, opposite the Wickham brickyards, which is reproduced in fig. 88.

Figure 88. Section on the Eastern Side of Old Park Wood, Plumstead.  
(J. G. GOODCHILD.)



Scale about 12 feet to an inch.

- a. Loamy brickearth.
- b. More clayey brickearth, showing arched bedding over a hollow in the Chalk: pebbly in places.
- c. Broken-up chalk, with flint-pebbles and green-coated flints (derived from neighbouring Eocene beds), passing down into the next.
- d. Undisturbed chalk.

PROF. MORRIS seems also to have been the first to describe the great sections of Erith and Crayford. He said that "the deposit at Erith," which clearly is taken to include Crayford, averages "about 300 yards wide [an under-estimate]. It reposes on the chalk, though sometimes separated from it by a bed of coarse sand, containing rolled specimens of the plastic clay shells," and further on, "the bones, though dispersed throughout the whole, are more numerous in the bed of sand, which is either interstratified with, or underlies the brick-earth."\* Unfortunately, of the four sections described in this paper, the precise locality of one only, near Crayford, is given; though presumably the others follow on in order, northward, to Erith. As however I was fortunate enough to see the pits at their best, when cut far back into the rising ground, there is little need for other descriptions here. To give some notion of the extent and variety of the two great sections it may be stated that each took a whole summer's day for noting.

\* *Mag. Nat. Hist.*, ser. 2, vol. ii. pp. 540-542. (1838.)

PROF. DAWKINS\* has described the sections ; but unfortunately has classed some of the Drift as Woolwich [and Blackheath] Beds, having been misled by the fallen or transported masses of these (see p. 141).

Many details, presumably taken at about the same time as my own, have been given by MR. A. TYLOR,† to whose paper, with its five figures of actual sections, the reader is referred, for comparison. This author saw that the masses of Woolwich Beds etc. were not in place.

The sections first to be described, close to Erith, can be seen no longer, for the most part. At a visit in 1887 the brickyard was found to be abandoned.

The following notes of the sections in the great brickyard at Erith (on the western side of the road, south of the town) were taken in the summer of 1867, when I examined the pits in detail, their general character being however well known to me before, some few remarks indeed being added from notes taken in 1861.

The eastern face of the large pit was old and much hidden, so that it showed very little, but the order of the beds could be made out to be as follows :—

Irregular loamy gravel, of pebbles, small flints, and pieces of race, with broken fossils from the Woolwich Beds.

Clay and sandy clay ; at the northern part greenish and with race at top ; southwards brown and buff, with race and shells (*Corbicula fluminalis*, &c.) ; further south this gets more sandy in the lower part, or is underlain by sand with freshwater shells.

The section of the southern and clearest face is shown in fig. 89. In 1861 I was told that at the deeper part they had sunk through the brick-earth, and then about 6 feet of sand and 7 or 8 feet of gravel, when the Chalk was touched. Westward the brick-earth thins, and Thanet Sand and Chalk are found below. The section went a few yards further west than is shown in the figure, but was either shallow, or hidden by fallen earth.

The western face showed from 15 to 20 feet of brick-earth over Thanet Sand and Chalk, and has already been described (see p. 113) the underlying beds being here the more important. At the northern part of the pit there was no section.

One of the most interesting parts of this brickyard was the westerly extensions of the pit, from the upper part of the western face. One of these was a long narrow cutting, about 20 feet deep (just north of an old footpath or lane) showing at first brick-earth over gravel over Thanet Sand. Further on, at the top, a mass of brown clay (? London Clay) overlying a pebble-bed, and some masses of the clay shell-beds of the Woolwich Series, all of which must be fallen or transported masses. Higher up there was again brick-earth and gravel.

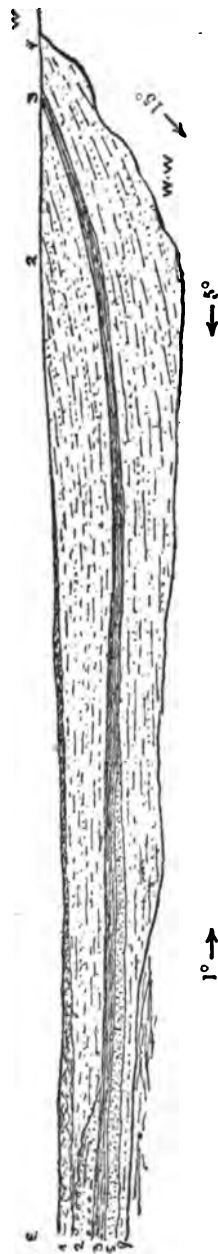
The other and more northerly extension, directly north of a cottage, and approached by a long narrow cutting, was much longer, and at first was in brick-earth and irregular, partly false-bedded gravel: further westward the Thanet Sand came up for a short distance and the Drift-beds were only about 12 feet thick: still further these latter consisted of gravel only, fine, and made up in great part of flint-pebbles: then brick-earth again came on over the gravel, part of which was hardened by iron-oxide. A bed of yellow and buff sand then came in, and thickened westward; it was bedded and false-bedded, and had layers of flattish concretionary lumps and masses of sandstone.

\* *Quart. Journ. Geol. Soc.*, vol. xxiii. pp. 97, 98. (1867.)

† *Ibid.*, vol. xxv., pp. 85–89, pls. iv., viii. (1869.)



Figure 89. Section shown by the Southern Face of the Great Pit at the Erit's Brickyard, 1867.



The Arrows &c. show the amount of dip at the spots above them.

1. Soil and wash, lessening westward.
2. Brown brick-earth with race, over 15 feet at the most, and with signs of bedding. Contains pebbles, and pieces of shells from the Woolwich Beds.
3. Darker brown clay, with a little race, about 5 feet, with a little grey brick-earth (with shells) at the bottom, passing down into the bed below.
5. Sand with shells (*Corbicula fluminalis*, &c.) and pebbles, less than 4 feet for the most part; loamy at top in parts, and gravelly at bottom. Thins out as the ground rises westward.
9. Brick-earth with a little pebble-gravel. At the west divided thus:—Brown loam with a layer of hard race at the bottom, 4 to 5 feet or more; underlain by buff or grey sand, bedded by thin layers of loam, 4 feet shown.

The numbers of the beds are the same as those in the Section at Crayford (fig. 92), and the section is at the same part as Mr. TYLOR's figure 17.

At the deeper part of the section, opposite the engine-house, the divisions almost die out, and we find some 30 feet of brown brick-earth, with about 3 feet of gravelly capping, the clay bed (3) which is not well marked, being at about the middle: below it are a few thin lenticular masses of gravel (chiefly pebbles, and with broken shells from the Woolwich Beds), the lowest part being sandy and finely bedded as usual.

At the western end of the cutting, where it widened out into a pit there was a singular section. On the north-eastern side, and for a great part of the north-western, the beds being as follows:—

Clayey top earth.

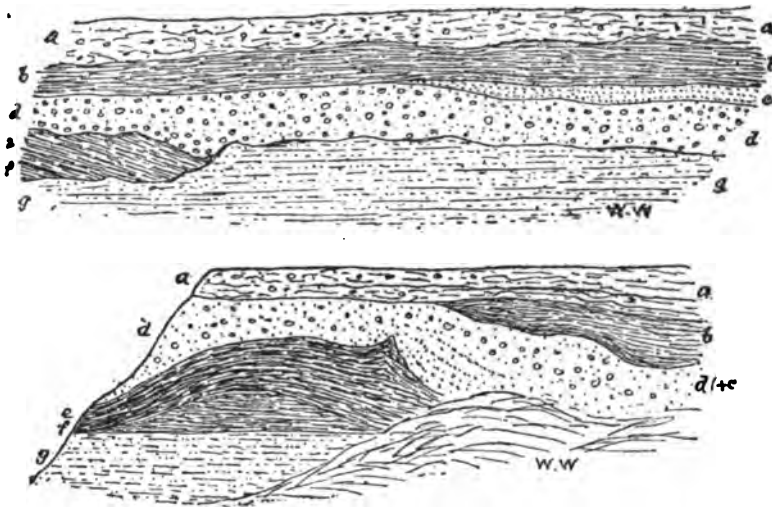
Brown brick-earth, finely bedded and false-bedded, with great numbers of broken-up shells from the Woolwich Beds, a few flint-pebbles, and sub-angular fragments of flint, and a little race; 12 feet or more.

Yellow and buff sand, with concretionary sandstone, as described above; sometimes tending to pass upwards into the brick-earth; about 4 feet.

Gravel shown below at one part.

It is the brick-earth with broken shells and the sand with stone that have been mistaken for true Woolwich Beds.\*

*Figures 90, 91. Sections of an Old Landslip, or of Transported Masses of Eocene Beds, overlying the Drift at the Western Extension of the Erith Brickyard. 1867.*



a. Brown clayey soil, with a few flint-pebbles, 2 feet or more.

b. Dark brown stiff clay (London Clay) 3 or 4 feet.

Fallen { Blackheath { c. Fine buff sand, 0 to 15 inches.

Beds. { Beds. { d. Sandy pebble-bed, 4 feet.

e. Clay shell-bed of the Woolwich Series.

Brick-earth { f. Dark brown clay.

Beds. { g. Finely bedded brick-earth.

At the western or south-western part of the pit however there occurred at the top, in parts, the remarkable set of beds illustrated by figures 90 and 91, above. Of course all the masses of the older Tertiary beds must either have been transported, or must have slipped, into their present place, as they rested on the brick-earth, which moreover must belong to the upper part of the Drift Series here. Besides both the Blackheath and the Woolwich Beds here shown had but a fraction of their proper thickness, and most of the divisions of the latter were unrepresented (*see section, p. 142*). The most noteworthy fact however was the occurrence of a mass of London Clay, a formation of which no trace could be found in the immediate neighbourhood, the nearest patches seen, and those very small, being nearly two miles off. A small patch has however since been found little more than half-a-mile off (*see p. 231*). The occurrence of masses of the Woolwich Beds here has been

\* *Quart. Journ. Geol. Soc.*, vol. xxiii., p. 97.

noticed by Mr. A. TYLOR, as also of a like mass of Thanet Sand, 38 feet long by nearly 8 feet wide, embedded in "purple clay,"\* and he remarks that "the difficulty is to understand what kind of wash of water removed this incoherent mass of Thanet sands and deposited it again (without breaking it up into sand)."

Near by the great section first described was a smaller brickyard, just east of Northend (Crayford) the following note of which was made in 1861. At the western side of the pit the section was:—

Dark brown sandy clay with pebbles and broken shells (from the Woolwich Beds), 3 to 6 feet, resting with an irregular pipey junction on the next.

Light-coloured brick-earth with layers of sand, about 12 feet shown.

At the eastern part of the pit there was sandy gravel, full of pieces of chalk and with layers of sand, about 10 feet thick resting evenly on chalk, into which the workmen could not sink more than 6 feet, on account of the water. A little brick-earth must have been taken off from above the gravel here.

At Northend, on the southern side of Colyers Lane, a new pit has been opened, since the six-inch Ordnance Map was made, a little south of the Erith pit, and just N.W. of The Happy Home Inn. It was carried down to a depth of from 35 to 40 feet (in 1887), being deepest on the west, and showed a gentle dip (about 2°) into the hill westward. The brick-earth was evenly bedded, brown at top, and with a bed of grey clay, about a foot thick at, or above, the middle. It contained race in various parts, chiefly in layers.

On the eastern face the grey loam a little below the clay-bed showed contortions, with nests of sand (in which occurred *Corbicula fluminalis* and other shells), and at the base there was sand, with shells and stones.

At the southern part of the western face the grey clay-bed was seen to pass down into rather sandy brown clay, about 5 feet thick, which there rests on the bed showing the contortions. This last however is here a grey and brownish, bedded, sandy clay, not contorted; and beneath it a loam with race (chiefly in two layers, at top and bottom) seems to replace the sand of the eastern face. In this part the earth above the clay-bed was damp, whilst on the east it was not. The lowest beds seen were sands.

The Rev. O. FISHER has given the following account of the section at the north-eastern end of "Slades Green Pit," eastward of the railway:—

Trail of clay; about 6 feet.

Sandy brick-earth, with freshwater shells; 5 feet.

Pebbly band, with *worked flint* (see p. 341); 5 inches.

Gravelly brick-earth; 6 feet.

He has remarked that the brick-earth there "is deposited against an old talus of chalk, which had previously fallen from a cliff which formed the side of the river-valley at that place," and he concludes "that the river or estuary-waters remained for some while at a considerably lower level than that which they afterwards attained, when the flood-waters deposited the brick-earth. Such a rise of the water-level seems to require subsidence to account for it. . . . Whatever it may have been at some periods of its history, the Thames could scarcely have been at that time a tributary of the Rhine, but must have possessed an estuary of its own as at present, and probably the tide came even higher up than it does now."†

There is however nothing in the fossils to show the presence of this tidal action: rather the reverse, and a reference of the "cross-bedded sands of Gray's Thurrock" to tidal action is unfortunate, the current-bedding being in the direction of the flow of the river (see p. 420) and not such as would result from currents both up and down.

PROF. MORRIS described the Crayford pit as "on the right of the road leading from Crayford to Erith, about half a mile south of the former village . . . about 300 feet square, with a depth of 69 feet to the chalk"‡; but the section given shows less than

\* *Quart. Journ. Geol. Soc.*, vol. xxv. pp. 88, 89. (1869.)

† *Geol. Mag.*, vol. ix. pp. 268, 269. (1872).

‡ *Mag. Nat. Hist.*, ser. 2, vol. ii. p. 541. (1838.)

50 feet of beds. It is clear that at the time the opening had not reached anything like its present size.

In 1867 PROF. DAWKINS gave details of the section here,\* either taken at one spot, or generalized from various parts; but I cannot collate his divisions with those noted by myself, somewhat later, just as he was unable to see the same succession as that noted by PROF. MORRIS, on account of "the variability of the beds in the enormous pit."

Two years later MR. A. TYLOR published figures of eight actual sections in this pit, with descriptive details,† especially noticing the junction of the Drift against the cliff of Chalk and of Thanet Sand, the doubling over of some of the beds, and the waved bedding deep down in the brick-earth.

The discovery of flint-implements here has been already noticed (see p. 343).

In 1885 MR. GOODCHILD alluded to the waved bedding both at top and in the midst of the brick-earth,‡ and the next year MR. SPURRELL published some figures showing the irregular festoons (in section) of the surface-beds at Crayford and Erith.§

My notes of the sections in the great brickyard, just N.E. of Crayford and about a mile southward of that at Erith, were also taken in the summer of 1867.

The chalk-pit here, on the western side of the lane, which was then approached by a short tunnel from the large pit, shows the ending off of the brick-earth, as in figure 6, p. 112. The northern face of this pit gave a like section,|| with less Thanet Sand, but not so clear, and in the western face there is a hollow of Drift. The eastern side showed brick-earth over chalk, which latter seemed to be hard at the junction in parts. The even middle beds of the brick-earth did not conform to the irregular junction.

Along the western side of the great pit the beds were not divisible, as in other parts, but formed for the most part one mass of brick-earth, with alternations of more clayey and more sandy layers, the shelly sand and pebbly gravels, seen in other parts, having thinned out (except at the north). Near the southern end there was at the bottom a confused mass of gravel, &c., chalk-rubble, and fallen Thanet Sand, and the beds above were seen to rise westward and southward, showing that the brick-earth ended off almost directly. Just south of the tunnel to the chalk-pit this face showed 40 feet or more of brown bedded brick-earth, the upper half lighter-coloured, and at the bottom, where cut through, buff sand and gravel (flint-pebbles, subangular flints, small pieces of chalk, pebbles of sandstone and of quartz) a few feet thick, below which at one part rubbly chalk rose up. The chalk was also shown in the ponds at the bottom of the pit close by.

At the northern end of this face the beds were evenly bedded, and in the following order, the numbers being the same as those in figures 89, 92.

	FEET.
2. Buff and brown brick-earth, in parts very sandy, or with layers of sand - - -	about 12
3. Brown clay, with hard race at the bottom - - -	" 3
4. Brick-earth, as above (a few shells at the bottom, = 5) - -	" 7
6. Gravel - - -	" 1
9. Brick-earth, as above; the bottom 6 or 7 feet with layers of sand and others of small pieces of chalk (sometimes cemented together) - - -	" 18

\* *Quart. Journ. Geol. Soc.*, vol. xxiii. pp. 95-97.

† *Ibid.*, vol. xxv. pp. 90-95. (1869.)

‡ *Proc. Geol. Assoc.*, vol. ix., no. 3, pp. 156-153.

§ *Rep. W. Kent Nat. Hist. Soc.*, in text and in plates, 1886.

|| Fig. 22 of MR. TYLOR's paper (reversed).

Figure 92. Section shown by the Northern Face of the Great Pit at the Crayford Brickyard. (1867.)



1. Loamy Soil and Wash.
2. Brick-earth, more clayey to the east; about 12 feet at most.
3. Brown clay, with race. The top of this bed was less marked soon after leaving the north-western corner, and the beds just above were more like it; about 3 feet at most.
4. Brick-earth, clayey: about 7 feet.
5. False-bedded light-coloured sand (the shell-bed); about 5 feet. *Corbicula fluminalis* in great abundance in this bed.
6. Pebbly gravel, about a foot.
7. Brown clay, wedging out against No. 8, and thickening as that bed thins, so as to take its place.
8. A long lenticular bed of stiff, grey clay with race, over 4 feet. This does not come up to the surface, and is hardly distinguished from 7 in the figure.
9. Brown brick-earth, with race, and with a lenticular bed of pebble-gravel at\*, varying from a foot to 3 feet in thickness, and ending off at the north-eastern corner of the pit. The top 3 feet of the brick-earth is often darker, and the thickness of the whole is from 15 to about 20 feet.
10. Sand and gravel, false-bedded, with blocks of concretionary sandstone at top, 4 feet shown. This bed most likely rests at once on the Chalk.

The numbers of the beds are the same as those in the section at Erith, fig. 89, p. 434.

The northern face gave the clearest section at the time of my visit, and also showed the greatest variety in the beds, as may be seen from figure 92, which stops a very little short of the eastern end of this face, where little was to be seen. Contrary to what one would expect the beds rose slightly eastward, that is towards the marshes : and as the ground falls slightly in that direction the upper beds end off.

The eastern face showed some of the same beds as those of the northern face, with variations. Below the shelly sand (5) there were irregular beds of pebble-gravel, in the brick-earth a little below which I found shells (*Pupa* and *Succinea*). At one part the gravel, 6 feet thick, came directly underneath the sand, which latter was 6 feet and more thick. On the opposite (western) side, here very near, I got some specimens of *Cyclas* (? *Pisidium*), at a depth of over 40 feet, in grey laminated clay (like that of Grays, see p. 420) which must be 12 feet or more below the bed with *Pupa* and *Succinea*. At the southern end of the eastern side there was, below gravel, some 16 feet of brick-earth, the lower part laminated (with the laminæ puckered in parts), in which I found a *Succinea* and a small *Helix*. All these shells were very friable.

At the southern end of the pit, over 30 feet deep, there was brick-earth, with three thin layers of pebble-gravel (the thickest of them only 18 inches); the upper part brown, the lower part buff, laminated and partly puckered.

When last I saw the Crayford section, in the summer of 1888, the northern part had been cut back much further, even to touching the road (Howbury Lane), by Manor Farm, and it did not give so fine a section as that figured above, the beds being much like those noted at the newer North End brick-yard, and consisting of evenly bedded sand, loam and sandy clay.

At the western part of the pit, north of the chalk-pit, which is now joined on to the rest, a bed of loamy gravel, or stony loam, with large flints and pebbles of chalk, formed a low ridge, or "horse," in the loam, reaching up to about 15 feet from the surface and running a little E. of N. and W. of S. The gravel was up to 3 feet thick, and underlain by sand, and the ridge extended southward, to the north-eastern part of the chalk-pit, where the gravelly bed rested at once on the Chalk. It was by here that Mr. SPURRELL found so many worked flints (see p. 343).

Where the brick-earth pit turned into the chalk-pit, the northern face of the latter showed the brick-earth ending off against a slope of chalk, rising westward, whilst at top a mass of rubbly chalk came some way over the brick-earth, eastward.

The two patches on the higher ground of Crayford are of gravel, as also is the lower flat eastward of the brick-earth. In this, near the marsh of the Cray, is a slight ovoid rise, nearly half a mile long and a quarter of a mile broad, where a higher patch of gravel seems to be separated by a very narrow outcrop of Chalk, the latter being certainly not far from the surface at all events.

### *Between the Cray and the Medway.*

In the triangular tract between the Cray and the Darent, near their junction, there is a large mass of high terrace Drift, bordered by smaller patches, and also a little of a lower terrace, a continuation of that eastward of Crayford.

The large mass is on Dartford Heath and to the east, and has a steep indented slope on the west, to a great extent.

A pit on the southern side of the high road and about a quarter of a mile south of Bowman's Lodge gave the following section, in 1861; but in 1867 this long pit was in great part hidden :—

Brown brick-earth, about 5 feet, passing down into the next.

Brown, bedded, coarse, clayey sand, 3 or 4 feet.

Light-coloured, coarse sand, bedded and false-bedded, the lower part coarser, very full of small pieces of flint, and also with small pebbles, about 8 feet shown.

At a smaller pit close by the whole of the last bed was full of pieces of flint.

The section at Dartford Heath brickyard has been already described (p. 111) and Mr. SPURRELL has figured a section of "the gravel at Dartford Heath,

with brickearth lying in a gully or channel."\* At the eastern edge of the Heath there are pits in very evenly bedded gravel.

In a small brickyard about halfway between Wilmington Common and Church I saw (in 1867), at the northern side of the pit, some three or four feet of bedded pebble-gravel over brick-earth, and, at the western side, 13 feet or more of the latter, which was brown and buff, whilst in the middle of the pit a hump of chalk stuck up.

A little westward was another small brickyard, where the chalk was only about 9 feet down in places. The higher part of the brick-earth is here more clayey, and at one spot it has blackish layers. It has been found to as great a thickness as 16 feet.

Eastward of Crayford Station gravel and loam come on above the Chalk as the ground falls. Near the bridge for the high road the Chalk is at the surface, except for rubble and pipes of gravel. The eastern end of the cutting is in loam and gravel, resting irregularly on the Chalk, and the like is shown in a small ballast-pit on the south of the line.

The shallow western end of the next cutting is in brown loam, sand and gravel. Further eastward there is at one part a little clay above.

Before reaching, and at, the small bridge over the line (No. 27) there is light-grey, fine sand and loam, with freshwater shells of common living species.

Where the Lewisham and Dartford Loop Line joins the old North Kent Railway, westward of Dartford, the valley-beds end off against the Chalk. The former here fill a hollow in the latter, and are somewhat irregular, but the following is their order, as well as one could make out, where the section is deepest:—

Brown loamy soil.

River Drift.	{	Chalky and flinty wash. Light-coloured loam, or sand with patches of gravel. Dark clays and lighter-coloured loams, with race. Light-buff and brown sand; with bits of flint, chalk, and shells from the Woolwich Beds; at bottom with gravel (of flint-pebbles, flints, and small bits of chalk, with shells from the Woolwich Beds).
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My colleague Mr. PENNING has got the following shells from this cutting. — *Bithynia tentaculata*, *Helix*, *Planorbis corneus*, *P. marginatus*, *Valvata piscinalis* and *Pisidium amnicum*.

Crossing the Darent we find, from Dartford to Northfleet, a line (continuing westward through Dartford Heath) of separate masses of a high terrace, whilst along the lower ground, from Dartford to Stone, gravel borders the marsh.

A pit on the hill just east of the Dartford Powder Works showed, in 1861, more than 15 feet of roughly bedded gravel, of flints (many large) and flint pebbles, with layers of loam or sand. At the southern and deepest part the lowest 3 or 4 feet contained many pieces of chalk, and was full of broken shells derived from the Woolwich Beds. The Chalk was touched at one part.

MR. SPURRELL has figured sections at Dartford Brent, one showing gravel beneath "disturbed layers of brickearth," overlain by so-called "trail," the other, on the southern side of that place, "showing a gall or pipe [in gravel and sand] with disturbed seams and a cavity, taken in 1867."† That observer has also given me, in a letter (1883) the following section here:—

Loam.

Gravel, much waved or festooned.

Gravel, folded over on itself.

White or grey clay, largely formed of chalk, sandy in parts, stiffer in others; somewhat like reconstructed boulder clay. This clay folds over the gravel above.

Gravel, of a washed character, with mammalian remains, Eocene shells, and bits of shell (? *Gryphaea*.)

Chalk rubble, and then firm chalk.

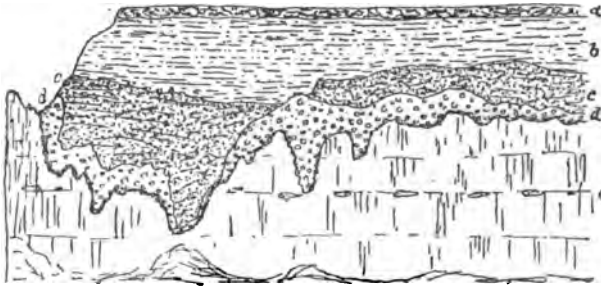
\* *Rep. W. Kent Nat. Hist. Soc.*, 1886, plate 1.

† *Ibid.*, plate i., figs. viii-x.

At the southern end of the great chalk-pit eastward of Stone, the Chalk is capped by brown, sandy, false-bedded gravel, 20 feet thick, composed of sub-angular flints and flint-pebbles, with some pieces of iron-sandstone and of sandstone. Further south there is a mass of brick-earth, with a gravelly capping.

At the southern part of the large chalk-pit S.E. of Greenhithe Station there is an irregular capping of gravel, chiefly on the eastern side (1861) and at one part a large pipe, 40 feet or more deep, of brick-earth with a little gravel at the bottom. Fig. 93 has been reduced from a drawing of this pit by PROF. HUGHES.

*Figure 93. Section in the Chalk Pit at the Western End of Greenhithe Tunnel, North Kent Railway. 1861?*



- a. Gravelly soil.  
 Valley { b. Reddish-brown loam, with pebbles scattered and in masses.  
 Drift. { c. Drifted Thanet Sand.  
 d. Gravel.  
 e. Chalk. Slight dip N.

At Milton Street and Swanscomb the southern boundary of the gravel seemed doubtful, there being clayey soil between those places, which may prove to be owing to the presence of brick-earth.

In the chalk-pit facing the Thames, north of Northfleet Railway Station, gravel, from 8 to 12 feet thick, was seen at top.

On the southern side of the high road, between the station and church, the pits for supplying the brickyard showed about 15 feet of brick-earth (of which 5 feet more has been found) consisting of sandy clay and clayey sand with seams of clay, often finely laminated, at the highest part capped by a little gravel. In a pit a little lower down westward there was brick-earth at top, lying on gravel at the southern end, but on the north passing into light-coloured coarse sand, finely false-bedded, with veins of gravel, getting more gravelly below and passing down into gravel; the gravel was full of pieces of chalk, and the layers of sand in it were full of broken-up shells from the Woolwich Beds; the chalk was touched at the bottom.

In the brick-earth there are sometimes layers of gravel, and the underlying gravelly beds contain bones and small pebbles of chalk.

The brickyard itself is a little eastward of the above, and on the northern side of the road, where there are some old pits, which, with the chalk-pits that supply the neighbouring Cement Works, gave the following section :—

Brown brick-earth	} 30 feet or more in many parts.
Gravel and sand, often full of broken shells from the Woolwich Beds.	
"Bull head," hard lumpy reconstructed chalk.	
Chalk with flints.	

The junction with the Chalk is slightly wavy, but even, not piped, and it dips northward.



From Northfleet there is but a slight trace of Drift (east of Milton) for nearly 4 miles, and again from Highain to near High Halstow, for about 5 miles, there is none; then however not only does a strip border the marshes, but large remains of a high terrace occur over the London Clay between the Thames and the Medway, sometimes apparently sloping down to the marshes of the latter river.

In the strip that skirts the marshes between Chalk and Higham, in a gravel-pit, on the northern side of the railway, at the eastern end of the cutting by Kings (Prince's Farm on the new ordnance map), there is light-coloured, coarse, false-bedded sand, with layers of gravel, passing eastward into sandy gravel, which is rather fine, consists of subangular pieces and pebbles of flint, is about 10 feet thick, and is capped by some feet of a clayey soil.

In the Hundred of Hoo the gravel-boundaries are often doubtful: thus the strip at the foot of the hills from Halstow Marsh to north of Allhallows seems to consist of a set of gravelly patches, with London Clay at or close to the surface at intervals, and much the same is the case with the higher mass of Hoo Common, and with part of that next to the east.

The apparent downward-incline of the mass E.S.E. from High Halstow to the brook on its southern side (judged by the hill-shading) is delusive, owing to the bad topography of the old map, for the brook runs alongside the road, to the south, and not where it has been engraved.

At Hoo St. Mary I found a palæolithic flint implement in a field by Hoppers, at the south-eastern corner of the gravel-mass, and another, likewise in a field, three eighths of a mile to the east, on the next mass.

Farther east, I found a third, but this time in a gravel-pit, though not in place, on the northern side of the road about three quarters of a mile S.W. of Allhallows Church. All these were much rolled.

By the road at Windhill, half a mile west of Allhallows, gravel was seen abutting vertically against London Clay.

The London Clay islands Binney and Grain have cappings of gravel, and in the latter there is a small patch at a lower level, touching the marsh north of Perrys.

At the large fort east of St. James' Church there were, in 1867, many cuttings in gravel and sand, partly false-bedded, over London Clay. The gravel consists of subangular flints with some flint pebbles and a few pieces of stone from the Lower Greensand, and is about 8 feet thick.

## CHAPTER 25. RIVER DRIFT.

### TRIBUTARY VALLEYS, SOUTH OF THE THAMES.

In dealing with the tributary-valleys we will follow the natural course, from above downward, beginning therefore on the west. With the chief tributaries on the southern side above London, the Wey and the Mole, we are not here concerned however, as they are outside our district.

#### *The Loddon.*

Along the small part of the valley of the Loddon in our district there is continuous gravel on the right, or eastern, side, forming a flat of some breadth above the tributary from Ruscomb Lake, with a doubtful boundary in parts, where the London Clay is almost as flat as the gravel. There are also two patches at a higher level, on the extreme south, at King Street.

The eastern boundary of the gravel is partly doubtful, the bordering London Clay being sometimes almost as flat as the gravel. At Hurst the former rises slightly from beneath the latter, but between that place and Haines Hill it is again flat.

The gravel near Ruscomb may belong in part to a higher terrace, extending from the west of Stanlake to within a mile of Wargrave; but it is doubtful whether this may not belong to the main valley rather than to the tributary. The railway-cutting and a large pit on its northern side give sections (see page 177).

Islands of gravel also occur, forming slightly rising ground surrounded by the marshland; one just west of Whistley Mill, another a little to the south, and a third S.E. of Sandford Mill.

There is also a little gravel in the side-valley eastward of Hirst, and in the longer branch of the same for more than two miles northward from Binfield and along the northern border of the marsh of Ruscomb Lake.

#### *Between the Mole and the Wandle.*

At the brickyard on the southern side of Barnett Wood Lane, about a third of a mile S.S.W. of Ashstead Station, the following sections were noted in 1887, by Mr. H. H. FRENCH:—

Chalky gravel, full of small pebbles, with large subangular flints; browner toward the base; 3 to 4 feet.

London Clay, seen to 8 feet.

Further south, above the gravel, there only 2 feet thick, were 2 feet of soil and 2 of light-brown loamy clay.

It is hard to say what this Drift is, but perhaps it may be connected with the stream on the north, which joins the Mole below Leatherhead.

At Epsom the junction of the Chalk and the Tertiary beds is in part hidden by gravel (with layers of sand, and sometimes with a few small pieces of chalk in the lower part). This runs for about a mile northward, along the course of the Hog's Mill Brook. On the right side of the same stream between Malden and Kingston there is also some gravel.

Along the Beverley Brook no gravel has been mapped, and the gravel near its source, at Sutton, seems to join on to that of the Wandle. At this place however there are small gravelly patches on the western side of Balaam Lane, towards Beauchamp Lodge, and Mr. FRENCH told me that bones of elephant had been found.

*Valley of the Wandle.*

In the dry valley in the Chalk south of Croydon there is but a narrow strip of gravel; on reaching the Tertiary beds however there is a large sheet, at first about three miles broad, from Croydon to Carshalton, and chiefly confined to the right side of the river, but narrowing irregularly northward, until at Wandsworth it is but an eighth of a mile broad.

There is also a rather higher mass on the eastern side of Croydon, where it is but slightly separated from the former. This broadens over Croydon Common and Thornton Heath, and then narrows, along the course of the tributary-stream (Norbury Brook), apparently joining the other sheet near Tooting, and also joining the gravel south of Wandsworth Common and Upper Tooting.

The boundary of these gravels is sometimes doubtful, and the London Clay may come up to the surface in places.

Taking first the higher terrace, there is a patch on Duppas Hill, in which flint pebbles are more plentiful than is usual; and on the hill just east the gravel reaches as far south as Haling House, and seems to join on northward to the lower mass in the valley. At Violet Lane, W. of Haling House, there is a small patch of brown bedded sandy clay, seen to a depth of 6 feet.

There is a large pit on the railway, south-westward of East Croydon Station, and here pieces of the tooth and of the tusk of an elephant are said to have been found; and sections have been opened elsewhere along the railways.

Gravel was seen, over London Clay, at a former brickyard, on the western side of the high road, at Broad Green; and at another brickyard, about a quarter of a mile N.E. of the cemetery, there was washy clay and sand over the gravel.

At the brickyard just west of Thornton Heath Station the upper part of the section might have been taken for London Clay, with traces of gravel above, had not gravel been seen below. The beds seen were as follows:—

River Drift	{	Clayey and stony earth.
		Brown clay (reconstructed London Clay), 5 or 6 feet.
		Gravel, 3 or 4 feet.

Sand of the Oldhaven Beds.

There was a gravel-pit on the western side of the railway a little N.W. of the station.

The shallow railway-cutting near Norbury is in gravel, and there was, in 1863, a very small pit in the field south of that farm.

The gravel reaches some way up the slope, toward the houses of Streatham Common.

Turning now to the lower and larger sheet, the left side of the stream is mostly free from gravel, Carshalton and Merton (where there is a triangular patch, the boundary of which is not clearly marked) being the exceptions, besides a small strip on the west of Croydon.

During the progress of the sewerage-works of the Croydon Rural Sanitary Authority Mr. W. S. CRIMP recorded the beds through which the sewers ran, and he has kindly given me a copy of his record, on the six-inch ordnance maps. This shows that the gravel everywhere reaches up to the High Street of Merton, and also spreads further eastward than is shown on the map.

At Beddington the gravel is mostly bounded on the south by the river itself.

North-westward of Croydon a small low hill of London Clay occurs, as an island, free from gravel.

In the large pit on the western side of the railway S.W. of St. Peter and St. Paul's Church, Mitcham, there is as much as 15 feet of gravel over the London Clay.

In Mitcham I saw some of the sewer-sections, with Mr. CRIMP. At the north-western part of Lower Green, near Church Street, these showed at one spot only  $3\frac{1}{2}$  and at another 6 feet of gravel over the London Clay.

Near Jacob's Green (a name that does not appear on the new Ordnance Maps) the London Clay rises up, northward of Merton Lane, and may be seen in the brickyard, near Obilton Place. At the higher part of the abandoned brickyard, close by to the north, and just south of the railway, the clay was capped by gravel, and on the east of this strip of clay gravel comes on at a slightly higher level.

The long, shallow, curved railway-cutting from just northward is in London Clay at the western end, but soon some small hollows and patches of gravel come on at top: then the gravel and sand gets continuous, the London Clay however being still touched below: then the latter rises to the surface here and there: and then the gravel is again nearly continuous, along the eastern end to the junction with the other loop of the railway.

The clay seemed to extend along the border of the marsh to the northern part of the Lambeth Cemetery; but as Mr. CRIMP has recorded gravel all along the high road, from Merton, to Tooting, it would seem as if there were two separate clay-tracts divided by a gravel-channel.

The clay is again to be seen in the cemetery and in the brickyard on the east.

The spread of gravel is bounded eastward by rising ground of London Clay.

### *Valley of the Ravensbourne.*

Gravel occurs along the bottom of this valley from its entrance into our district, near Hayes; but of any higher terrace there are but few and small traces.

There is a narrow strip of thin gravel (of pebbles) from the east of Woodside to the west of Beckenham, with an uncertain boundary throughout.

In the shallow cutting on the Addiscombe railway just south and east of the former place there is a little pebble-gravel here and there, and the like was shown along the lane across the line. This is too fragmentary to be mapped, but north-eastward there is more of it, for the holes dug to prove the ground (for the railway-works) were all in gravel, about five feet deep. Still further the gravel was worked for ballast: it contains irregular patches of sand, and is four or five feet thick. At Clay Lane was a shallow pit just east of the railway.

At the northern end of the strip the railway-cutting (south of the London Chatham and Dover line) showed brown sand, over the London Clay, at its shallow northern end, but near the bridge for the road pebble-gravel.

The traces of higher gravel in the main valley consist, on the left flank, of four mere dots southward of Bromley, formed by irregular gravelly patches, in the most northern of which, about half a mile W.S.W. of the Railway Station, there were some small pits in pebbly gravel. The way in which these small patches occur, along a curved line parallel with the boundary of the lower gravel, is suggestive of an old river-terrace. On the right side of the main valley, the low hill-top between it and its eastern tributary, by Lewisham, has a gravel-cap, which has been cut through by the railway (see p. 152).

On the western bank of the tributary stream at Laurel Brook, and some way up the hill, a pit showed from 10 to 12 feet of dark brown gravel, chiefly of flint-pebbles (partly in layers) but also with many more angular flints. This gravel does not seem to extend any distance, either north or south along the bank of the brook.

Just east of Catford Bridge Station there was a pit in gravel of rounded and sub-angular flints, with veins of sand.

Along the tributary-valley from Chiselhurst there is gravel from Mottingham downward, and also a patch of brick-earth, reaching some way up the slope of London Clay on the south.

At the former brickyards on either side of Burntash Lane the earth was for the most part clayey. In the eastern yard there were many pebbles, some-

times almost forming veins of gravel. The largest section was in the other yard; it was about twelve feet deep (1863), and showed a bed of stiff clay (like London Clay) in the middle of the brick-earth. Elephants' teeth have been found in the brick-earth here.

### *Valleys of the Cray and of the Darent.*

There is a narrow strip of gravel along the left side of the alluvium of the Cray throughout, whilst on the other side there are only small strips. In the small part of the valley of the Darent in our district the gravel is also confined to the left side, except for the narrow strip along the dry tributary-valley on the east.

Rather more than half a mile N.W. of Orpington church there is a small mound of sand, at the very top with gravel, of pebbles and subangular flints, many of the latter very large. This seems to be separated from the sheet of gravel below.

The gravel in the large pit on the southern side of the high road just west of Bexley is largely made up of flint-pebbles, as might be expected from the occurrence of the Blackheath pebble-bed on the ground above. It also contains broken-up shells from these beds.

On the right side of the Cray a small pit, just east of the house at Mount Mascal, south of Bexley, showed about three feet of gravel, chiefly pebbles, probably a wash from pebble-beds that once occurred near by.

To my friend Mr. T. HENNELL I am indebted for an account of the beds met with in making the sewer along the valley of the Darent, from Orange-tree Farm south of Dartford, along the road to Hawley, in the parish of Darenth, at the southern edge of the district.

At the meeting of the roads at Orangetree Farm a thickness of 8 feet of gravel was proved. A little south-eastward, at the cross-roads near Orange-tree Place, the section showed 14 feet of gravel underlain by wet chalk, to a depth of 4 feet. Farther south-eastward, by the field-hedge on the eastern side of the road, there was gravel, 10 feet thick, with running sand at the bottom. At Hawley, and for some way north-west, gravel and sand, with some clay occurred.

A pit in a field just S.W. of the high road nearly a mile S. of Dartford showed about 12 feet of gravel, mostly very coarse, with beds of sand here and there. At part of the southern side there was a little rubbly chalk, capped only by 3 or 4 feet of loamy soil. It is possible that the higher patch of Wilmington may be separated by a narrow outcrop of Chalk, instead of joining on to the gravel of the valley-bottom, as shown on the map; but the wash of gravel down the slope often hides such narrow outcrops.

A brickyard about a quarter of a mile south-west of Dartford church, gave the following section :—

Gravelly soil.

In parts an irregular gravel, sometimes 6 feet.

Light-coloured, bedded, fine, clayey sand (worked for brick-making), over 12 feet shown and said to go 3 feet lower, where there was found :—

Gravel (and water).

This brick-earth seems to end off suddenly on the west, against a hard mass formed of pieces of chalk and flints and a few pebbles, which was cut into in the sides of the basins for holding the prepared brick-earth, and also along the road, where however the chalk soon comes up, slightly covered by this chalk-gravel and a gravelly soil.

I was told that at a former brickyard, a little to the south, the earth was better (more clayey).

At the eastern end of the railway-cutting west of Dartford Station there is a set of light-coloured sands, light-grey loams, darker clays, and thin beds of gravel (chiefly of pebbles). In parts these last are full of broken-up shells, as also is the coarse gritty sand; and in fine sand at the higher part of the

cutting, and near where the deposit ends off against the Chalk, I found very many specimens of shells of recent species (*Bithynia tentaculata*, a small *Helix*, *Linnaea peregra*, *Valvata*) mostly broken but many whole, besides some specimens that might belong to *Corbicula fluminalis*.

On the other side of the Darent, at the junction of the side-valley, a little southward of the Dartford Powder Works, there is fine, buff, clayey sand, with a little calcareous matter.

It is but right to note that MR. SPURRELL, who has worked at the Drift of this neighbourhood for years, classes the thick mass of brick-earth at Crayford and Erith (described on pp. 432-439) as belonging to the valley of the Darent, rather than to that of the Thames. Certainly it seems to have been deposited near a former junction of the two rivers, including of course the Cray as part of the Darent.

### TRIBUTARY VALLEYS NORTH OF THE THAMES.

#### *Valley of the Loudwater and to the West.*

A narrow band of coarse gravel, partly covered by alluvium, reaches along the bottom of the Hambledon Valley. MR. J. H. BLAKE notes that "much flint gravel occurs in the valleys in the neighbourhood of Fingest and Turville, which frequently has to be excavated to a considerable depth before any water is met with." Great part of the gravel here is in the higher branches of the valley, which are usually dry.

In the valley of the Loudwater again the greatest spread of gravel is in the higher branches, above West Wycombe, where there is usually no running water at the surface, and in the Hughendon tributary much the same is the case. I must however express my doubt of the expediency of separating such spreads as "Dry Valley Gravel," which has been done on Sheet 7 of the map. The valleys may be dry now, but may have been the reverse in the River Drift time. Moreover the rising-point of a stream in a chalk-tract is often a very varying one, miles higher after a wet season than after a dry one. Whilst allowing that there may be gravelly deposits in chalk-valleys that have not been formed by water flowing at the surface, yet it is very difficult to separate such deposits from true stream-drift: the two must pass into one another.

MR. JUKES-BROWNE has sent the following notes of the gravel in the higher part of the valley of the Loudwater.

"At the head of the valley, near Saunderton, are two patches of gravel which seem originally to have been continuous with the main mass, and to show that this gravel was formed before the spring-heads in the Chalk Marl (see p. 61) had cut their way so far back into the valley, that is to say when the valley had a more prolonged northerly extension than it has now."

"The northern part of the main mass is more than half a mile wide but narrows southward; it consists of flints in a sharp sandy matrix. At Grange Farm a well showed 6 feet of it, above the Chalk."

"Wycombe Workhouse (not marked on the old map) stands on gravel which forms a broad bank or ridge occupying the central part of a tributary-valley, this valley having been excavated to lower levels on either side since the deposition of the gravel; the flanking slopes have in fact retreated from the ancient valley-bottom occupied by the gravel."

Of the beds further east MR. H. B. WOODWARD writes as follows:—"Along the tributary-valley of Hughendon there occurs a deposit, from 4 to 12 feet

thick, of clayey loam with layers of flint-fragments, which are sometimes so many as to give the deposit the appearance of a gravel. It is well shown in road-cuttings a little way eastward of Warren, north-eastward from Bottom Farm, and near Temple Farm."

"It is evidently of subaërial origin, and results from the action of rain and streams washing down brick-earth and clay-with-flints from the hills on either side."

This deposit is again seen at Copy Farm, on the right bank of the main valley above High Wycombe, where it is very gravelly; below the town, on the left bank, by Rye Mill to Bowden; and in the small side-valley from King's Wood."

The alluvium of the valley is most likely everywhere underlain by gravel, as also would be the case in other Chalk-valleys to be noticed.

### *Valleys of the Colne and of its Tributaries.*

Along the Colne itself there is little River Drift, the only masses of importance being on the right bank, below Rickmansworth and at Denham. The tributaries too are without gravel in their lower parts, though in all cases there is probably some beneath the alluvium.

It will be convenient to take the valleys in their order, from west to east, leaving the main valley till last.

#### *Valley of the Misbourn.*

In this valley, as in that of the Loudwater, there is much gravel in the higher and usually dry branches. Of these parts Mr. JUKES-BROWNE has made the following note:—

"The gravel commences just south of the spring-head south-east of Wendover and forms a well-marked bank or ridge which gradually merges into a flat southward. A gravel-pit by the side of the main road 6 furlongs south of Wendover showed 12 to 14 feet of gravel, consisting of angular flints in a siliceo-calcareous matrix, formed apparently of comminuted chalk and flint particles, and resembling a kind of rough mortar. The surface portion was decalcified into a loose, brown, sandy gravel, which was piped into the calcareous mass below, presenting a strong contrast in colour."

"At Great Missenden the alluvium begins, and water always runs in the winter. Just above this village, the gravel of the main valley is joined by a similar strip, which runs along Hampden Bottom and has been dug for road-material here and there."

Down to Amersham the gravel is but slightly covered here and there by alluvium. In a pit at the eastern corner of Shardeloes Park (and opposite Mantles Green) the gravel is 12 feet thick. Below Amersham but very narrow strips of gravel could be mapped, for a little way only on the left side, and to Chalfont St. Giles on the right.

#### *Valley of the Chess.*

MR. H. B. WOODWARD notes that in the bottom of the valley north of Chesham "angular flint gravel is well shown, and it spreads up to Hobbs Hole and Nash Leigh. Probably the greater part of the town is built on it. There are traces above Halfway House, in the other fork of the valley, and by Amy Mill; and at Canons Mill, a mile below the town, the gravel is shown by the road-side."

Below this only a very narrow strip has been mapped, eastward from Flaunden, on the right side.

#### *Valley of the Bulbourne and of the Gade.*

We now pass to valleys that have their origin beyond our district, northward.

On the road just above the railway about a mile E.S.E. of Berkhamstead Church one of my colleagues noted the occurrence of red sandy gravel consisting of flints and flint-pebbles.

MR. A. G. CAMERON notes that at "Chaulden House Gravel Pit, opposite Boxmoor House, flint-gravel, with a red clayey matrix, was found to the depth of 10 feet."

At Crouch Field, on the northern side of the stream, near its junction with the Gade, was a brickyard, the pits supplying which showed pipes of gravel, with here and there a little brick-earth, on the Chalk. At a higher level, towards Green End, there is a terrace of gravel, many feet thick, and at Frogmoor End, below the junction of the two streams, there is more of the like. I learn from DR. J. EVANS that a tooth of *elephant* was found in the gravel near Apsley Mill, in making the canal.

At King's Langley Railway Station some coarse gravel rests irregularly on the Chalk.

#### *Valley of the Colne.*

The head-waters of this stream flow, in great part, over a mass of Glacial Drift, and it is therefore not easy to make out whether there is also any Drift of later age.

MR. H. B. WOODWARD supplies the following notes of this part:—

"Gravel occurs in the tributary-valley between South Mims and North Mims; but at the latter place it seems lost in the Glacial Drift. From the former place to Mims Street it keeps to the course of the stream and presents the features of a River Gravel. On the banks of the stream N. and N.W. of North Mims Church there is an interbedding of gravel and brownish clay."

"It also occurs somewhat irregularly along the tributary-stream north of Elstree, between Kendall and Old Organ Halls."

MR. BLAKE notes that "much loam occurs over the low ground bordering the alluvium, south of the Colne, for some miles below Bushey."

On the right side of the valley just below Rickmansworth the gravel seems to reach some way up the gentle slope of the Chalk.

On the western side of the valley just above and below Denham there is a broader mass of gravel, divided by the alluvium of the Misbourn; and about a mile south of the village brick-earth has been worked.

#### *Valley of the Brent.*

MR. J. L. LOBLEY has remarked that "the Brent gravels are . . . dissimilar to the Thames gravels in not being so ferruginous, as well as being otherwise differently composed," and he has given the following analysis of 821 stones examined\* :—

Flint-pebbles, unbroken, 221.

Flint-pebbles, broken, 549.

Quartz-pebbles, 30.

Fragments of granitic rocks, 21.

MR. WOODWARD notes that "gravel occurs along the course of the Brent from S.E. of Hendon to the Welsh Harp, and probably in the area taken up by the reservoir. At Kingsbury Church there is a patch of a higher terrace," and another just south, whilst two others occur eastward of Alperton. Of the lower strip, from Kingsbury to Twyford, MR. WOODWARD says that the boundary is not well-marked.

MR. J. A. BROWN says "in an excavation, about 7 feet deep, recently made for a sewage farm near the bridge over the Brent at Alperton, I noticed a bed of gravel at the base of which was the large stone ballast, so characteristic of the basal bed of the high terrace deposits to the south; and from which a block of sarsen fully 3 feet across (weighing probably about 7 cwt.) was taken along with other larger boulders of the same kind."†

\* *Proc. Geol. Assoc.*, vol. x., no. 4, p. 149. (1887.)

† *Paleolithic Man in N.W. Middlesex*, p. 50, 8° Lond., 1887, and *Quart. Journ. Geol. Soc.*, vol. xlii. p. 195. (1886.)



On the northern side of the Brent, from the east of Greenford to a little beyond Perivale, there is a gravel-flat about a quarter of a mile broad, the western part separated from the stream by a strip of London Clay from which the gravel has been denuded. This seems to join on, across the stream, to a like strip on the other side.

### *Valley of the Lea.*

The Lea is the only one of the tributary-streams that has a very large sheet of gravel. This occurs, without a break, on the right, or western, side from Broxbourne to Tottenham, the extreme width, from the marsh to the outcrop of the London Clay on the west, nearly reaching 3 miles. This gravel, over which there are many cappings of brick-earth, forms a plain with a general gentle rise away from the stream. There is some sign of a terrace-division from Broxbourne southward, nearly along the high road, to Cheshunt, and probably this is continuous further south, with a like line that I traced, also close to the high road, from south of Waltham Cross nearly to Edmonton; and it should be remembered that this work was done on the old one-inch Ordnance Map, without the advantage of levels and of contours. On the higher or western side of the apparent terrace between Enfield Highway and Edmonton the ground sometimes slopes slightly westward, or away from the river, and I was in doubt whether there might not be a small outcrop of London Clay in the lower ground in that direction.

The outer, or western, boundary of the great sheet of Drift is somewhat irregular, owing in great part to the cutting away of the gravel by side-streams; but in part also to original deposition along winding hills of London Clay.

On the other, or eastern, side of the valley there are but small patches of gravel, until we reach the tract of the Thames Drift, already described, and it would seem therefore that, in deepening its valley, the Lea has here tended to work its way eastward, cutting back in that direction into banks of London Clay.

Notwithstanding the large area taken up by the Drift no very notable sections were seen, though gravel-pits were common and brickyards occur.

In 1871 Mr. WOODWARD noted that "the two valleys N.E. of Northaw are much obscured by an alluvial deposit, or rainwash, composed of loam, and pebbles of flint and quartz. Blocks of puddingstone also occur. At the junction of the two streams near Enfield Chase this gravelly deposit is of thickness enough (3 feet) to be worked, and it is largely derived from the Pebble Gravel, traces of which occur immediately to the south-west. There was one large pit showing from 10 to 12 feet of gravel composed mainly of pebbles of quartz and of flint with a few broken and subangular flints."

In the small outlier, of a higher terrace, at Forty Hall, Forty Hill, gravel has been got to a depth of over 12 feet.

S.E. of Southgate there is gravel, which may belong to a higher terrace. It has been much worked west of Hazlewood, and may be seen in the large pit there.

Turning now from these detached masses to the great sheet, on the west of Cheshunt Street, and east of the reservoir, brick-earth has been largely worked, to the depth of 8 or 10 feet.

On the southern side of the side-stream at the western part of Turkey Street there is a gravel-cliff, and just eastward the junction with the London Clay was seen.

A thickness of 9 feet of brick-earth was seen at a brickyard on the western side of the high road between Enfield Highway and Enfield Wash, the upper part being brown and the lower of a lighter tint; the same thickness was seen in another brickyard over half a mile S.W. of Enfield Highway Church, and a thickness of 7 feet at a brickyard at Ponders End, half a mile west of the high road, in which last the gravel beneath was reached.

At the brickyard at Tottenham, west of the high road, the gravel seemed (1863) to rise up sharply from beneath the brick-earth at the western end. The lowest foot or so of the latter was whitish, stiff, and with a few pebbles and flints, the rest being of the usual brown colour.

At the junction of the railways south of Tottenham Station, gravel was found, below 2 feet or more of brown loamy soil, and was worked to the depth of 7 feet. It was bedded, and false-bedded (in a westerly direction) in the upper part.

### *Valley of the Roding.*

In this valley there are only small patches of River Drift, mostly skirting the Alluvium on either side, but sometimes as remains of a higher terrace on the flank.

MR. WOODWARD notes that "below Chipping Ongar, at Langford Bridge, Kelvedon Hall Wood and Great Apsey Wood (Navestock), gravel occurs in patches, bordering the river or the Alluvium, and little above the level of the latter."

"At Owlet Hall, westward of Navestock, a pit showed 6 feet of gravel, chiefly of subangular flints, but with pebbles of flint and of quartz, and with a loamy top, 2 or 3 feet thick. This gravel reaches up to higher ground above the Hall."

"E. of Stapleford Abbots an irregular clayey gravel occurs, about 5 or 6 feet thick, and chiefly composed of subangular flints, but most of it has been worked away."

"At Jackson's Farm, eastward of Theydon Bois, there is a patch similar to that at Owlet Hall, which reaches to higher ground on the north. Below this, southward of Theydon Bois, is a longer patch, of which however much has been worked away."

"By Chigwell Lane Station (Loughton) a small patch, originally about 6 feet thick, has mostly been worked off."

MR. F. J. BENNETT notes that, on the other side of the river, "northward of Wolston, gravel was seen to the depth of 5 or 6 feet."

There were two brickyards just east of Buckhurst Hill Station; at the more southerly the pit showed a gravel-wash over brown clayey brick-earth with a few small bits of flint, some parts being quite a clay and like London Clay, but the lower part was said to be more sandy. At the lowest part of the yard, near the brook, I saw about 3 feet of gravel, chiefly of flint-pebbles. At the northern yard the pit was at a higher level; it showed a more sandy brick-earth, with small gravelly patches, and the London Clay seems to be touched at the bottom in parts. This brick-earth contains "race."

I was told (in 1872) that at the sewer-works, below the station, gravel and sand were found.

Up the Ingrebourn Valley MR. WOODWARD notes that "at Newhall Farm, north of the high road, and by Harold Wood Station angular and rather clayey gravel was seen on the London Clay. It is of a patchy character, and there is probably more than is shown on the map. These gravels may belong to the Drift of the Thames."

### TRIBUTARY VALLEYS OF THE FORMER THAMES.

We now leave the tributaries of the existing Thames; but the Essex rivers Crouch and Blackwater, which now flow direct to

the sea, must in former times have been affluents of the Thames, when England extended further eastward.

The first of these rivers is almost without Drift, the only trace seen being, as described by MR. WOODWARD, "a little patch at Little Hayes, eastward of Rettenden, of fine angular flint gravel, with quartz pebbles and sand." He adds however that "higher up the stream, south of Great Burstead, an excavation showed gravel, beneath an alluvial wash of stiff brown clay, 4 to 5 feet thick.

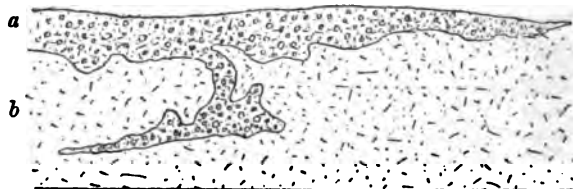
*Valley of the Chelmer and Blackwater.*

Here and there along this valley there are patches of brick-earth and gravel, of no great extent, except in one case, and sometimes of doubtful age, as might be expected from the fact that Glacial gravel occurs abundantly, and sometimes reaches down to the marshes.

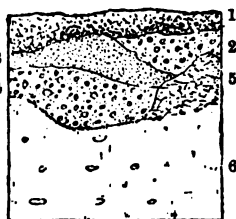
The islands in the estuary have gravel-cappings, whilst in the marshes there are some islands consisting wholly of gravel.

MR. WOODWARD says that "the large brickyards at Moulsham, Chelmsford, show brick-earth of various kinds, the relation of which to the Glacial gravel and sand is not clear. From the absence, in sections of that gravel, of any similar brick-earth, and from the position of the deposit, it seems best to regard it as Post-Glacial. The remains of *Hippopotamus major*, from Moulsham, in the British Museum, no doubt came from this brick-earth." Figures 94, 95 show the irregularity of some of the beds.

Figures 94, 95. Sections in the Moulsham Brickyard. (H. B. WOODWARD.)



a. Clayey gravel, irregularly on and in loam b.



1. Loamy soil.
2. Sandy gravel.
3. Sand.
4. Gravel.
5. Clay (piece of London Clay).
6. White marly clay and loam, with "race."

Of these brickyard-sections MR. BRISTOW has noted the following details:—"In one of the large brickyards east of the railway a well was dug 32 or 33 feet before 'blue till' [? London Clay or Boulder Clay] was reached: the section in the yard was as follows:—

Brick-earth.

Gravel, of pebbles, sometimes in a matrix of loose sand, sometimes in pale clay.

Pale bluish, sandy clay, with small pieces of chalk and iron-pyrites with wood, shells and mammalian bones, amongst others *Hippopotamus*. From this clay white bricks are made.

"Opposite the cemetery-gate the top of the brick-earth is eroded into potholes and contains seams of brown clay. The gravel is angular, and under the fence, a pit showed at least 6 feet of fine clean pale brown sand, above which there seemed to be an irregular deposit of gravel, chiefly consisting of flint-pebbles, but containing angular flints, and with layers of brown clay and of ferruginous sand, with flints and some quartz-pebbles."

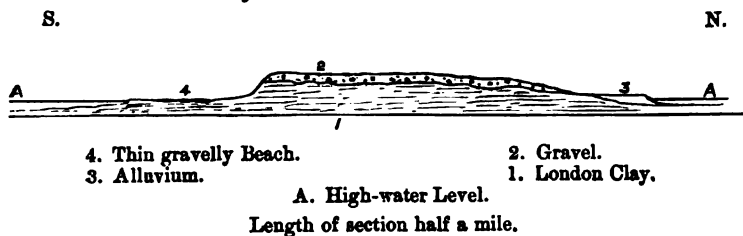
Of the other (northern) side of the valley Mr. BRISTOW noted (some 25 years ago) that "there were large brickyards in the area southward of the railway station. The brickearth was 5 feet thick; beneath came 10 feet of gravel, and beneath that brown tile-clay [London Clay], proved to a depth of 12 feet." No brickearth has been shown on the map, however, possibly because it has been worked away. MR. WOODWARD adds that "it was probably a valley-deposit, newer than the neighbouring Glacial Drift. The gravel may be of like age, or may be Glacial."

On the northern side of the valley, from Langford to Goldhanger a fairly broad strip of gravel has been mapped, which MR. W. H. DALTON says has a depth of 10 or 12 feet; but at the extreme east, at Bounds, MR. WOODWARD found only 2 or 3 feet of gravel.

The small patch of gravel on Northey seems to end eastward by the farm, at and westward of which it reaches down to the alluvium on the north, whilst to the south the London Clay rises up. The gravel can be seen under the bank at the edge of the salting, west of the farm, and on the northern side of the road thence to the farm a pit has been dug in it to the depth of 6 feet, showing a black layer, about half way down, in places (1887). This gravel was not originally mapped, and my former colleague MR. T. V. HOLMES was good enough to tell me of its occurrence. In adding it to the map it was found that the higher ground of the island had been carried (as London Clay) a little too far northward.

MR. WOODWARD notes that "Osea has a capping of gravel 4 to 5 feet thick, which forms a low cliff, resting on London Clay, on the northern side of the island, as shown in fig. 96."

Figure 96. Section across Osea.



## CHAPTER 26. ALLUVIUM, ETC.

## GENERAL REMARKS.

THE more recent deposits of our rivers are distinguished from the River Drifts by their fineness of texture. Depression of the land having decreased the rain-fall, the smaller and less powerful streams were unable to carry the coarse gravelly material characteristic of their earlier more torrential state, and for the most part therefore formed deposits of silt, or mud, fine-grained material, mostly of a clayey character, but sometimes sandy and even gravelly. The clayey sediment has become more compact, by pressure and drying, forming the marsh-clay, which is an impure and often sandy clay, more or less charged with vegetable matter.

With the above there is often a deposit of a more interesting kind, giving in some cases direct evidence of the existence of a land-surface on the spot and at others only of its proximity, namely peat. It is this peat which, when laid bare at low water along shores where estuaries join the sea, has been magnified by the name of "submerged forests." As peat occurs along the tidal Thames, often at some depth below low water mark, it clearly shows (where rootlets occur in the marsh-clay beneath), that, when it was formed, the land must have been at a slightly higher level than now: the subsidence therefore which brought our country to its present level, from the higher one that it seems to have had in the earlier times of the River Drift, had not finished at the beginning of the Recent period.

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We have seen that the River Drift occurs chiefly in the main valley of the district, that of the Thames; but it is curious that this does not altogether hold with the more modern river-deposit. To the west, above London, there are for the most part but narrow strips of marshland bordering the river, the only notable spread of alluvium being the famous Runney Mead, north of Egham, and that for its historical association and not for its size. Up to Walton-on-Thames these strips are not only very narrow, but often short also, so that they make but little show on the map; the river indeed flows sometimes between gravel-banks, and must everywhere have been confined within a narrow channel. The tributary-valleys have broader marshes than the main one.

Immediately below London however a very different state of things begins. There are broad marshes, on either side of the river, which touches firm land only at some of its bends, at Greenwich, Woolwich, Erith, Greenhithe, from Northfleet to Gravesend, and at Allhallows, on the south, and on the north only at Purfleet, from Leigh to Southend, and at Shoebury.

There can be no doubt that this fact had much to do with the selection of the site of London, which is built on the first spot, going up the river, where a broad low-lying tract of dry land comes down to the stream. This tract consists chiefly of gravel, cut through to clay in the shallow side-valleys, along which many springs of water must have issued, and it is well fitted for settlement, being plentifully supplied with water, though free from flood, and not commanded by neighbouring high ground. It should be remembered too that in those early days the river below London showed a different scene from that we see now. Instead of the broad marshes, carefully protected, by earthen walls, from the stream (now practically a canal), which at high tide is some feet above the marsh-level, the river then flowed through mud-plains, covered with water at high tide only, and at low tide showing broad spreads of treacherous mud, cut through by creeks and channels, such as may still be seen to a less extent in places, as at the Blythe Sands, on the south, and near Southend, on the north.

London therefore is on the first spot where vessels going up the river would find the narrow low water channel close against ground of the most favourable kind for permanent occupation, ground indeed yielding every advantage that our distant fore-runners in the land could have wished for. Their choice has been fully ratified by the long range of generations who have built up the great city.

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MR. F. C. J. SPURRELL, who has paid much attention to the alluvial deposits of the Lower Thames, has lately given a capital account of them, in a paper on "Early Sites and Embankments on the Margins of the Thames Estuary,"\* from which the following extracts are taken.

This lower part of the river "was, at a remote period, a stream whose waters were not estuarine or salt. At that time the land through which it flowed was so high as to keep the sea wholly away. But then came a time when the land had subsided so far as to permit the ocean to take possession of the freshwater channel. By the continued sinking of the land, the sea gradually crept up the valley until, at the present day, the ordinary tide reaches as far as Richmond."

"But the old freshwater bed at what is called the mouth of the Thames had sunk much further below the sea level than that at Richmond by the time the sea had reached the latter spot, and in doing so had afforded room in its bed for successive deposits of mud and refuse . . ."

"In the Thames, as elsewhere, these deposits are arranged in certain order, and about the Shorne and Tilbury marshes, for example, the layers of materials take a greater regularity in their relative positions than elsewhere. Coarse gravel lies lowest,

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\* *Archaeological Journal*. 1885.

smaller above, and then fine sand [these are River Drift]; this succession denotes the decrease in velocity of the current of fresh-water. Next we have sand banks in which the shells of *Scrobicularia* and *Tellina* occur [the sand at the base of the alluvium, at Tilbury, etc.], these are estuarine shells and announce the access of salt water. Above these comes a layer of peat formed of stranded trees and other vegetable matter, the current at that time having been checked sufficiently to let even floating logs lie." There is sometimes however marsh-clay between the sand and the lowest peat. "Above is found a very fine grey mud, then a layer of peat formed of land and freshwater plants, [? merely a local intermittent bed in the marsh-clay] above this fine grey mud, then peat again of considerable thickness and toughness, much more commonly formed of brushwood than of water plants, then grey mud again," to which the Tilbury section (see p. 467), on which probably the above is chiefly based, adds yet another peat and more marsh-clay. "The alternations of these layers denote intermissions in the rate of subsidence—mud was deposited when washed by the tide continually, peat was in formation when subsidence had either stopped or was reduced to a minimum (if, indeed, it does not show a reversal of the movement); so that the level of the soil had sufficient time to rise by its growth above the reach of spring tides, even in storms. Lower down the river this division into layers grows less distinct, while higher up the different peat beds merge into each other with less mud between." My own view is rather that some of the peat-beds thin out up the river, and this indeed our author allows further on. "In the marshes of Long Reach and nearer London, the upper layer of the great mass of peat supported a forest of birch, elm, hazel, and yew, with many others. The yew forest is a remarkable feature—as the yew is intolerant of water and cannot live in salt [water]—yet the yew forest stretched across the whole marsh," from Plumstead to Erith. "The stubs of the trees may be seen . . . on both sides of the river bank in Longreach standing *in situ* . . . Oaks of medium size are also found on both sides of the river in this layer. Long periods of freedom from the tide must have elapsed for such forest growths to have become established."

"The successive layers extended further and further westward as the land sank further, the lowest layers in the east not being represented in the west."

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The depth of some of the peat-beds in the marshes is not wholly due to subsidence; for to some extent shrinkage has helped. It may be seen, from any part of the old embankment which keeps off the tidal water from the marshland, that the surface of the marshes is some feet below the level of the river at ordinary high tides; whilst, on the other hand, the saltings, or unreclaimed alluvial tracts which are still open to the waters, are at a higher level, being covered only at high water of spring-

tides. Originally of course the level of the unenclosed marshes must have been about the same as that of their present narrowed representatives, the saltings; but, after enclosure, the alluvial mud has dried, becoming marsh-clay, and losing in bulk from the loss of moisture. As regards the age of the river-walls MR. SPURRELL says, in the paper above-quoted, "of banks against the tide in the district below Purfleet there are none surviving of the Roman period, while above that place none or but the slightest ones were needed, and no signs of any can be found. Some Saxon banks, perhaps, exist below Gravesend . . . while above it, with the exception of Littlebrook walls [in the parish of Stone], there are none now known of older date than the thirteenth century."

### VALLEY OF THE THAMES.

#### *Above London.*

Above London sections were rarely seen, and the only notable ones were at Hampton.

Some years ago the excavations for the additions to the water-works here gave fair sections, through the alluvium and gravel of the lower terrace, to the London Clay. At the eastern end of a new filter-bed (for the Southwark and Vauxhall Company), east of the old filters, the following beds occurred:—

Alluvium	{	A little brown clay, in parts 3 feet thick.
		A little greenish, sandy clay, with common freshwater shells; only close to the river.
		Sandy and rather peaty, dark clay, with shells and a few flints, as much as 4 feet.

Sandy flint-gravel, with the original brown colour washed out; at one part, where there is a slight rise of the London Clay, only 6 feet, but mostly thicker.

Dark grey London Clay.

The alluvium seemed to be about eight feet thick near the river, but thinner inland. A little way from the river there was, between the alluvial clay and fine gravel, a bed of coarse sand with common freshwater shells, nearly two feet thick, but near by almost nothing.

Along the western face of No. 3 Reservoir the alluvium was about seven feet thick for some way (at the middle part) and consisted mainly of brownish clay, partly iron-stained, below which was a thin bed of green clay, and then about a foot of peaty clay, which rested on sand (belonging to the gravel). The green clay did not run northward. Just before ending off in that direction the alluvium scooped down into the gravel, and was ten feet thick, the bottom part being peat with stems and twigs. At the northern end, where the gravel is not covered by alluvium, its upper part was brown, and the lower with the colour washed out, the whole being about ten feet thick, to the London Clay. On the eastern side of the excavation the section was much the same, and the alluvium also ended off with a peaty hollow.

#### *London, North and South.*

Westminster is built on alluvium, and was once an island (Thorney); but the boundary between the alluvium and the gravel is not well marked. "In the Roman time the Thorn-eye on which Westminster abbey church stands, consisted of sand



surrounded, or nearly so, with peat or marshland. The hard part of the little island where there was no peat was apparently covered with Roman buildings,\* of which remains have been found.\*

There seems also to be a little alluvium in the slight-bend between the Upper Pool and the Lower Pool, judging by the following notes:—

SIR C. LYELL has referred to a vessel, of which "the interior was filled with fluviatile silt . . . disinterred where the St. Catherine Docks are excavated in the alluvial plain of the Thames."†

The following "section at the excavation of the New London Docks at Shadwell, 1856" is from a MS. presented to the Geol. Soc. by MR. RIDSDALE, and begins at 9 feet below high-water level.

	FEET.
[Alluvium.] { River Deposit (silt, &c., human bones) -	6
{ Peat (prostrate trees) -	5½
{ Light-blue clay -	1
Flint gravel (Walrus skull found 33½ feet below T.H.W.M., most likely fallen in from the silt above) -	14
[London Clay.] { Hard, brown clay -	1½
{ Yellow clay -	12½
[Reading Beds?] Hard, close sand -	3

There is a border of alluvium on the Surrey side of the Thames from Lambeth to Deptford, again with a doubtful boundary at first; and westward of Bermondsey there may be more than has been mapped, judging by some sections to be described; south of that place and of Rotherhithe the broader spread is fairly well marked.

MR. C. EVANS has described some sections that were shown in the excavations for the arches of the South Eastern Railway from Charing Cross to Cannon Street, as follows:—†

"To the east of the Blackfriars-road, at a distance of about a quarter of a mile from the present bank of the river, these excavations have passed through various strata, the most constant of which was a bed of sandy clay with vegetable matter and fragments of unrolled flints. Near the bottom of most of the trenches beds of loam and clay were met with containing wood, freshwater and land shells, and insect remains. Mammalian bones have also been found low down in the excavations. These deposits rest upon a bed of sand and gravel." The details of the deepest sections, at William Street, Southwark, were as follows, but "the measurements are merely approximations":—

	FEET.
Made earth -	about 7
{ Bluish clay, with much vegetable matter and a few freshwater shells -	6
{ Earthy peat -	5
Alluvium, about 19 ft. { Earthy peat, with patches of sand and clay, many shells, and large blocks of wood -	2
{ Shelly sand and clay, with patches of peat -	1
{ Earthy peat, with patches of shelly sand and of light-drab clay -	1
{ Peat -	4
Gravel and sand.	

The first and last beds of peat "are of very local occurrence, and do not extend as far as the next parallel street to the east. The shell-beds extend rather farther, but appear to thin out to the east," for at the third street there

\* F. C. J. SPURRELL, *Archaeological Journal*, 1885.

† Principles of Geology, vol. 2, p. 260. (1882.)

‡ *Proc. Geol. Assoc.*, vol. i. no. 9, p. 264. (1863.)

was nothing but four feet of made earth and a foot of yellow clay above the gravel. A shelly clay was also found "at the excavations of the same railway in the Waterloo-road," and "at some drainage works in the road leading to Southwark-bridge." A list of the shells that were found in these cuttings is given on pp. 477, 478. Besides these the wood of alder, beech and hazel, with nuts and seed-vessels, were found, and wing-cases of beetles.

In describing some sections showing remains of piles, on the other side of the Thames (see p. 471), GEN. PITT-RIVERS has said that "similar piles in every respect have . . . been discovered in New Southwark Street . . . the points are driven into the gravel; the peat is three to four feet thick . . . and Roman pottery is found at all depths in the peat."\*

The south-western face of the excavation for the engine-house (? for a hydraulic accumulator) at the Willow Walk Station of the London Brighton and South Coast Railway (adjoining the Bricklayers Arms Station) gave the following section, in 1880 :—

		FEET.
Made ground	- - - - -	about 1 to 2
Alluvium ;	{ Clay or mud - - - - -	up to 2
the beds	{ Dark green or blackish peaty earth or earthy	
passing	{ peat, with bits of wood - - - - -	1 to over 2
into one	{ Blackish mud, with wood - - - - -	about 1
another.	{ Grey mud, with roots - - - - -	0 to over 1
Gravel and sand.		

Some roots went through from the base of the peat into the top of the gravel. Near the centre of the excavation the gravel rose up nearer to the surface.

At the south-eastern corner of the Goods Yard the following was the section :—

Made ground, 2 feet.

Alluvium { Yellow clay, changing to the next, 2½ feet.  
Blue clay, with vertical roots and stumps of trees, 5½ feet.

SIR C. H. GREGORY has said that "the first embankment (of the London and Croydon Railway), after leaving the Greenwich Railway, lies upon the peat, which is there about 10 feet in thickness, and beneath it are 4 feet of loose silt and 4 feet of shingle (gravel) on the top of loose chalk, the whole full of water to within 3 feet of the surface."†

I saw the following sections, in the works of the East London Railway, south of the Thames Tunnel, Rotherhithe, in 1868 :—

Between Adam Street and Albion Street (near the entrance to the old tunnel) :—

Made ground.

Silt, about 3 feet.

Valley Drift { Sand with a little gravel, about 6 feet.  
Sandy gravel.

Further south, at the entrance to the railway-tunnel, (the site of a station) on the western side :—

Soil, &c.

Alluvium { Brown clay, 3 feet.  
Peat with wood, 4 or 5 feet.  
Green clay.

A few yards further south :—

Alluvium { Peat, 3 feet.  
Grey clay, with rootlets, greenish in parts, 2 feet or more.  
Sand, with freshwater-shells (*Bithynia*), about a foot.  
Peat, with loam at the bottom, over a foot.

Sandy gravel.

\* *Anthrop. Rev.*, no. 17, p. lxxviii. (1866.)

† *Proc. Inst. Civ. Eng.*, vol. iii. p. 138.

Before getting to China Hall Gate there was clay 4 feet thick, over peat; and just north of where Deptford Lower Road crosses the railway, the alluvial clay, from 3 to 6 feet thick, and with a little peat at the bottom in places, was seen to rest directly on gravel.

The cutting by that road is in marsh-clay, about 6 feet thick, over false-bedded gravel, and a little further southward the following beds were shown :—

Alluvium	{ Soil and clay; 2 or 3 feet.
	{ Peat, or rather peaty earth; 1 or 2 feet.
Gravel.	{ Clayey sand, partly greenish; 2 or 3 feet.

Beyond the second bridge over the line, southward, the beds shown were dark clay, 2 or 3 feet thick, over a little sand, over gravel.

In a notice of an excursion to the Surrey Commercial Docks the following account of the section shown by the excavations is given :—“The cutting is about 40 feet deep, and about halfway down is a very excellent section of an ancient forest-bed, several trees remaining *in situ*. Below this is a band of silty clay, and this has been found especially rich in mammalian remains; and still further down are the lower level gravels. One of the most important results of the visit was the discovery of what, on further examination, will doubtless prove to be a line of fault hitherto unexpected.”\* It is to be regretted that a detailed account of the section has not been given, as well as some of the evidence for the supposed fault.

Crossing to the Isle of Dogs, on the northern side of the river, we find marshland which is really continuous with the long tract to Purfleet, next to be described, being separated, at the surface only, by the Lea, which we may here conveniently take as the boundary of London.

In 1866 sections at various parts of the Millwall Docks, showed the following beds, varying in thickness, and some beds being absent here and there. The peat is sometimes thicker towards the river, and comes down on to the gravel :—

Alluvium	{ Clay, about 2 to 6 feet.
	{ Peat, made up of small bits of wood, and apparently with rootlets, which run down into the bed below sometimes. I was told that bones and horns had been found in this, and at one place oak-piles; about 2 feet.
Valley Drift, about 20 feet	{ Clay, sandy at bottom, about 3 feet.
	{ False-bedded buff sand, in parts.
Light-grey firm sand, 7 feet shown below the gravel, at the graving-dock (P Woolwich Beds).	{ False-bedded gravel.
	{ Light-grey firm sand, 7 feet shown below the gravel, at the graving-dock (P Woolwich Beds).

MR. W. T. BLANFORD (late of the Geological Survey of India) recorded the following section, in 1854, from “an excavation lately made to join two portions of the West India Docks” :—†

		FEET.
[Alluvium, 8 ft.]	Made earth (clay, gravel, soil, &c.) - - - -	about 12
	Brown and blue clay, varying in character and thickness, with a few freshwater shells - -	about 4½
	Peat, also varying in character and thickness, with stems of trees (most lying horizontally, but some of the smaller being vertical). A great number of land and freshwater shells at the bottom at one place. Specks of blue phosphate of iron. Rests on an uneven surface of the underlying beds -	about 1½
	Clay of variable character, passing down into sand -	2

\* *Science Gossip*, no. 133, p. 20. (1876.)

† *Quart. Journ. Geol. Soc.*, vol. x. p. 433. The words in square brackets are my own.

	FEET.
Sand and gravel, the former prevailing in the upper part, the latter ferruginous at the top, and much coarser towards the bottom: much false-bedded	13½
[Blackheath Beds?] Pebbles and rolled clay, with broken shells ( <i>Ostrea</i> , <i>Cyrena cuneiformis</i> , <i>Pectunculus</i> ); also patches of green sand with remains of plants and insects. The pebbles are mainly of flint, but some are of quartz and of different kinds of sandstone (not bottomed)	10
Hard calcareous rock with <i>Cyrena</i> [Woolwich Beds] found, in a boring near by, a few feet lower down.	- ? about

The following section was shown along the side of Green's Dock, Blackwall, "about 1878," according to a tracing deposited in the Geological Survey Office.

Made ground; from about 11 to 14 feet.

[Alluvium]	{ Peat, thickest near the river; 3 to 7 feet.
	{ Sand and clay, thinnest near the river; from about 1½ to 8 feet.
[River Gravel].	Ballast, thickest near the river; from about 14 to 23 feet.
Blue [London] Clay.	

In "The Diary of Samuel Pepys" there is the following entry, dated September 22nd, 1665:—"At Blackwall. Here is observable what Johnson tells us, that, in digging the late Docke, they did, 12 feet under ground, find perfect trees over-covered with earth. Nut-trees, with the branches and the very nuts upon them; some of whose nuts he showed us. Their shells black with age; and their kernell, upon opening, decayed, but their shell perfectly hard as ever. And a yew-tree, (upon which the very ivy was taken up whole about it,) which, upon cutting with an adde, we found to be rather harder than the living tree usually is."

#### *Northern Side, from the Lea to Purfleet.*

The long sheet of marshland from the Isle of Dogs to Purfleet is rarely less than a mile broad, and is unbroken, except for the flowing through it of various tributary-streams, beneath which however it is continuous. Some fine sections have been opened in this tract.

In his paper just quoted MR. BLANFORD says that a peaty and clayey deposit, with stems of trees (like that at West India Docks) "occurs at the excavations now making for Victoria Docks," at which place he noted the section below:—

	FEET.
[Alluvium, { Brown clay, with some land and freshwater shells	6
15 ft.] { Peat	4
{ Sandy clay and sand with roots of trees	5
Gravels and sand, false-bedded	about 20
Blue [London] Clay, apparently unfossiliferous.	

According to MR. W. J. KINGSBURY the beds were as follows:—\*

		FEET.
Top soil	- - - - - about	1
[Alluvium]	{ "Various thicknesses of yellow and blue clays," at the entrance 8 to 9 feet, but averaging	5 or 6
	{ Peat - - - - -	5 to 12
Gravel	- - - - -	7 to 10
London Clay, at a nearly uniform depth of 37 feet below Trinity high-water mark.		

In 1878 I spent a day in June in examining the sections at the Royal Albert Docks (Victoria Docks Extension). At that time the southern face of the great dock was open, besides some other parts of the work, and one was enabled to see the excavation well.

\* *Proc. Inst. Civ. Eng.*, vol. xviii. p. 486. (1859.)

At the western end the base of the dock is gravel, hardened at top in part, and probably underlain by the shelly clay of the Woolwich Beds.

Going towards the south-western corner there was much peat, more than 10 feet thick, and reaching nearly up to the surface, as well as nearly down to the gravel, the top of which last seems to sink towards the south. The peat was very woody and crowded with trunks of trees: beneath it was a little clayey sand.

At the south-western corner there was clay, 3 or 4 feet thick, above the peat, and going eastward, along the southern face of the dock, this clay thickened.

At the corner of the first graving dock black gravel rose up from under the peat (with trees), but just round the corner clay came in between the two. At the end of the graving dock the section was:—

Alluvium	{	Clay, over 5 feet.
		Peat, about 9 feet.
		Finely bedded light-coloured sand, clay and loam, with a layer of gravel about the middle; over 6 inches.
Gravel and sand, 3 or 4 feet.		

Just before getting to the eastern corner of the graving dock (and opposite the other corner) the clay was 12 feet or more thick, with 12 feet of peat and peaty earth beneath, and then grey sandy clay.

At the eastern corners of the graving dock the gravel rose up to within 15 feet of the surface, and a little way eastward, along the main dock, to 2 feet nearer, when it fell again.

At the corners of the next graving dock there was clay, up to 12 feet; then peat, 2 to 3½ feet; then 4 or 5 feet of sand with peaty lumps.

At the top here there were masses of the Woolwich Beds, in part large concretionary stones, apparently the "tip" from the older Victoria Docks on the west.

Farther east the following section was noted:—

Clay, brown at top, grey below, 9 feet, passing into the bed below.  
 Earthy peat, 4 feet.  
 Pale grey clay, 4 feet.

Thence the section continued much the same for some way. At one place two thick tree trunks, respectively 30 and 21 feet long, were seen.

Farther east a ridge had been left near the middle of the dock, for a long way, and in going along this the gravel was seen to rise up (E. and N.), at some places being only 7 feet below the surface. It was overlain by peat, with clay above, and at one part there were rootlets in its sandy top.

Hereabouts was found the canoe, of which some 16 feet was preserved. This I saw at the Engineer's Office, and was the means of securing it for the British Museum. MR. F. C. J. SPURRELL tells me that he saw the boat some time before (in place) and that it occurred at the bottom of a hollow of clay, cut through the peat to fine sand.

Still further, in the middle of the dock (which seems to have been cut along an E. and W. ridge of gravel, under the alluvial beds) the section was as follows:—

Clay, about 3 feet.  
 Peat, less than a foot.  
 Stony sand, about 7 feet.  
 Bedded gravel, about 12 feet.

Farther eastward the gravel sunk, on the southern face (with thin peat over), but kept high in the middle and on the small part of the northern face still open. The sand above it was persistent.

Farther a section across the middle part of the dock showed the sand and gravel rising up on the N.N.W., and then, the excavation turning at a right-angle, falling again. This, however, does not affect the clay at the top; but only the peat, which thins over the ridge, along which it would seem therefore that a channel had been cut. Fig. 97 is from a sketch made here; but should have shown a tree-trunk at the bottom of the peat, lying on the slope of the sand, above the asterisks.

Figure 97. Section in the middle of the Royal Albert Dock, a little west of Ham Manor Way.



About 60 yards long and about 15 feet high.

- |             |                            |
|-------------|----------------------------|
| Alluvium    | { 1. Clay.                 |
|             | { 2. Peat.                 |
| River Drift | { 3. Sand, 7 feet.         |
|             | { 4. Gravel, 3 feet shown. |

Beyond Ham Manor Way the peat sank to a fairly low level, but gravel was shown at the bottom.

At one spot MR. SPURRELL found remains of Roman pottery, etc., "between 8 and 9 feet below the surface . . . on and in the top of a layer of peat."\*

The following section, at the Metropolitan Sewage Works at Gallions, was noted by MR. J. G. GOODCHILD in 1887, in "a large rectangular excavation east of Beckton Gas Works":—

- |                |   |
|----------------|---|
| [Alluvium.]    | Marsh-mud, drying into irregular prisms; 4 to 7 feet.   |
|                | Earth and clay, mixed with a varying amount of peaty matter and locally taking the character of peat. Stems of trees (birch, alder, hazel, etc.) here and there, mostly prostrate: a few stumps in nearly the position of growth, being probably snags, sunk root downward. Hazel-nuts and elytra of beetles. A few mammalian bones found by the workmen (skull of deer). Passes down in places into the next bed; 5 to 9 feet. |
|                | Lead-grey marsh-mud, like that above, with scattered remains of trees, less in number downward. The bottom part black and carbonaceous; 3 to 4 feet.  |
| [River Drift.] | Clean sharp rather coarse sand, locally false-bedded, and interbedded with gravel, mostly of flints; 5½ feet seen.  |

The cutting for the sewer of the "Metropolis Sewage and Essex Reclamation Company" at Barking Creek showed peat in good thickness and containing many trees. I was told that a yewtree nearly 50 feet long had been found. Along the course of the sewer northward there was a little clay above the peat, which continued to yield tree-trunks, and the cutting for a tramway, under the railway, south of Mays Bridge, showed the clay over gravel, which last rose up northward until it reached the surface at the edge of the marsh. These works were abandoned.

Of Dagenham Marsh, further east, we have some interesting old records.

In 1712 the REV. W. DERHAM† described the occurrence of trees in the alluvium "uncovered by an Inundation of the River of *Thames* in *Dagenham* and *Havering* Marshes." He said that "the Inundation happened between Four and Five Years ago, by a Breach in the *Thames* Wall, at an extraordinary high Tide: And by means of the great violence of the Water, a large Channel was torn up, or Passage for the Water of 100 Yards wide, and 20 Foot deep in some Places . . . By which means a great number of Trees were laid bare, that had been then interred many Ages before."

"The Trees were all, as far as I could perceive, of one sort, except only one, which was manifestly a large Oak, with the greatest part of its Bark on, and some of its Heads and Roots. The rest of the Trees the Country People . . . take to be *Yew*: And so did I myself imagine them to be, from the hardness, toughness, and weight of the Wood, notwithstanding we have no *Yew* growing any where thereabouts, and it seem'd strange to me, that *Yew* should grow, in such vast quantities, in such a soil, and so near the brackish

\* *Archæological Journal*, 1885.

† *Phil. Trans.*, vol. xxvii. pp. 478-484.

waters. But . . . *D'Acre Barret Esq*; convinced me they might more probably be some other Wood, as *Alder*; which grows plentifully by our fresh Water Brooks” . . .

“By lying so long under ground, the Trees are become black and hard” . . .

“There is no doubt but those Trees grew in the Place where they now lye; and that in vast multitudes, they lying so thick upon, or near one another, that in many places I could step from one to another. And there is great reason to think, that not only the Marshes, which are now over-flown (which are about 1000 Acres) are covered underneath with those Subterraneous Trees, but also all the Marshes along by the River side, for several Miles: For we discover these Trees all along the *Thames* side over against *Rainham, Wennington, Purfleet*, and other Places: And in the Breach that happened at *West-Thurrock* about 21 Years ago, they were washed out in great Numbers (as I have been informed)” . . .

“Most of the Trees, that I met with, had their *Roots* on, and many of them their *Boughs*, and some a part of their *Bark*. There was only one that I perceived had any signs of the *Ax*” . . .

“As I passed the Channel which the Water had torn up, I could see all along the Shores vast Numbers of the *Stumps* of those Subterraneous Trees, remaining in the very same posture in which they grew, with their *Roots* running some down, some branching and spreading about in the Earth . . . Some of those *Stumps* I thought had signs of the *Axe*” . . .

“The *Soil* in which all those Trees grew, was a black ouzy Earth, full of the *Roots* of Reed; on the Surface of which ouzy Earth the Trees lay prostrate, and over them a Covering of grey Mould . . . about 7 or 8 Feet thick, in some places 12 Feet or more.”

“The trees lay . . . in no kind of order, but some this way, some that, and many of them across: Only in one or two places I observ'd they lay more orderly, with their *Heads* for the most part towards the North, as if they had been blown down by a Southerly Wind.”

With regard to the way in which the trees have been interred our author well says “this I take to be from the gradual increase of the Mud, or Sediment, which every Tide of the *Thames* left behind it” and this “is farther manifest from . . . the likeness of the Earth above them . . . to the Sediment the River now lets fall.”

A few years later CAPT. JOHN PERRY described the measures taken to repair the breach in the river-wall, and for the following extracts from his book\* I am indebted to MR. T. V. HOLMES.

“Moorlogg is a vein of divers sorts of rotten Wood (Yew Timber only, which is found amongst it being not decay'd) which lyes about 3 Foot and a half, or 4 Foot underneath the Surface of the Marsh Ground belonging to the Levels, about 10 Foot in depth, and with very little mixture of Earth that can be discerned amongst it; underneath it there is about 12 or 15 Inches depth of blew Clay, then Gravel and Sand. A great Part of this Moorlogg seems to be composed of small brush Wood, and many hazel Nuts have been taken up in digging, which I have had in my Hand and looked to be firm, but upon a very little pressure they break to Dust.”

“Some of the Yew Trees are found 14 or 16 Inches Diamiter and are perfectly sound, excepting the Sap; the Willow or Sallow Trees are many of them found some of two Foot and upwards Diamiter, and retain a whitish Colour like Touch-Wood, and so decayed (where they lye) that Men cut into it with their Tools, with more ease than they do the Earth or adjoining Moorlogg. But I have never seen any of that sort of Wood which others have described to be taken up Sound, and to moulder away upon its coming into the air.”

“There have been found a little above the vein of this Moorlogg, Staggs-horns, particularly, my Men lately Loading of Earth into a Barge . . . found a Staggs-horn of a middle size, the largest part of it quite rotten, and mouldered to Dust in taking up, and other parts honey-combed and rotten, and the small Branches near the top (of which I have two by me) one of

---

\* “An Account of the Stopping of Dagenham Breach” &c., pp. 72, 73, note. London 1721.

10 Inches, the other of 7 Inches and a half length are heavy, and the most Part Sound "

" From what Cause or by what Means this thickness of Moorlogg which is found underneath the Surface of the Marsh Ground (as described) has been produced and generally lies in Even and Regular Manner, being nigh 6 Foot thick above in the Thames, at Deptford, where Capt. Bronsdon lately repaired his Docks, in Woolwich Reach over against the Ballast Wharf between 7 and 8 Foot, in Plumsted Levels against Barking Creek 9 Foot: And gradually of a greater Thickness as well as Breadth, going down on both sides of the Thames below the Breach, as the Marshes extend; the Thickness of the Marsh Ground which lies upon it being near alike, and none of it to be seen at any Place where the Course of the River cuts into the Highland (as at Woolwich, Erith, Purfleet, &c.) I say from what cause this has been I will leave to Gentlemen who may employ a Thought this way, and will omit my own Opinion." Truly a most cautious captain!

From the map given in this book it is shown that the inundation reached right across the marsh, to the left of the gravel, from the stream westward of Dagenham down to Rainham Creek, and also some way up the little valleys of the stream in question, of that to Dagenham (and its eastern branch), and of that to the east.

Mr. S. V. Wood, Jun., remarked in 1874, that " at Dagenham Docks . . . the trench was open some four or five years since, and the section of the forest on the gravel exposed. There was a heap of the peat hard by, and out of this you could pick sprays and leaves of oak as fresh as out of any ditch bottom where they had only laid a year or two."\*

#### *Southern Side, from Greenwich to Greenhithe.*

Of the mass between Greenwich and Woolwich all to be said is that stiff, dark, bluish-grey alluvial clay was worked for bricks, just westward of the Dockyard.

From Woolwich to Erith is a broad marsh, in which good sections were seen from the former place to Crossness, in the trench cut for the Southern Outfall Sewer through Plumstead Marsh.

At the part north of Plumstead Church the following section was noted:—

Alluvium { Clay; upper part brown, lower bluish-grey; about 5 feet.  
Peat; with wood at bottom, some of the pieces being very large; about 10 feet. Bones have been found in this.  
Gravel, of pebbles and small subangular flints; with water.

The same beds go on eastward, but in parts the clay thickens, to as much as eight feet, at the expense of the peat, and I was told that the clay sometimes reached down to the gravel. In places there is some light-green clayey sand between the peat and the gravel. The irregularity of the deposits is well shown by Fig. 98.

In a popular account of "The Ancient Thames" Mr. H. WALKER has noted that "an old forest bed . . . was found lying at a depth of twenty feet below high-water mark . . . the tree-trunks are found lying flat in immense numbers, and the peat is almost exclusively composed of the twigs and leaves of trees. At the base of the peat the stools of trees—of yew and oak and pine—were found rooted, in some cases, in the gravel."†

Mr. S. V. Wood, Jun., also "followed the forest from Woolwich Arsenal to Crossness Point continuously. Hundreds of trees had been dug out, and were lying on the surface." At the excursion for which this note was written and the account of which was written by Mr. WALKER, "oak and alder were recognised, a catkin of the latter being remarkably well preserved," and "some articles of furniture made from oak taken out of these marshes during the excavations" were exhibited.‡

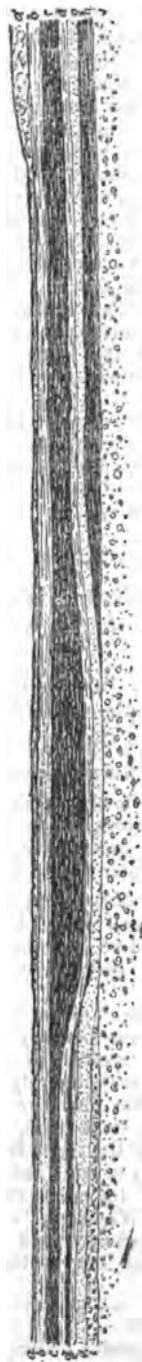
\* *Proc. Geol. Assoc.*, vol. iii., no. 6, p. 267.

† *Saturday Afternoon Rambles round London: Rural and Geological*, p. 139. 8<sup>o</sup> London, 1871.

‡ *Proc. Geol. Assoc.*, vol. iii., no. 6, p. 266. (1874.)



Figure 98. Section nearly along the Western Side of the Reservoir, Southern Outfall Sewer, Crossness.  
Reduced from the large Plans of the Metropolitan Board of Works.



Scale (vertical and horizontal) | | | 88 feet to an inch.

a. Soil.

b. Brown silty clay.

c. Peat.

d. Blue clay.

e. Peat.

f. Blue clay.

g. Soft sand and clay.

h. Soft peat and clay.

Old River Gravel { i. Fine sandy gravel.  
j. Grey subangular flint-gravel.

MR. SPURRELL measured two yew trunks, which were 15 inches and over 18 inches in diameter respectively, and remarked that "there were others larger still which I did not measure." He also noted, at the outfall-works, Crossness, "much Roman pottery, mortar, tiles, rubbish and portions of wood, lying about 9 feet below the surface . . . on the upper part of a layer of peat, which showed unmistakably that hazel and birches were growing on it, while moss, &c., covered the surface . . . large quantities of native oysters and snail shells lay in the peat."\*

From Erith to Stone there are marshes, through which the Darent flows, and again, barely separated from this, in the bend of the river, at Swanscomb.

In digging for the foundations at the Paper Mills abutting on Dartford Creek the following beds were found, according to a statement in a local newspaper, and "a large quantity of bones were found between the peat and the sand":—

		FEET.
[Alluvium]	{ Loam	- 1½
	{ Peat	- 5
[River Drift]	{ Sand	about 1½
	{ Gravel	- 2

The marsh-clay was worked for bricks nearly half a mile northward of Stone Church.

#### *Northern Side, from Purfleet to Leigh.*

A long border of marshland skirts the river from Purfleet, where it is only just separated from the sheet above that place, down to Leigh. It is very narrow between West and Grays Thurrock, at which last place indeed it is almost divided, the river all but coming up to the gravel.

From a mile to half a mile westward of Grays the gravel crops out from beneath the alluvium almost on a flat, so that the line between them is not strongly marked.

The fine sections shown by the excavations for Tilbury Docks have been noticed by MR. T. V. HOLMES,† who has also corrected the error into which SIR R. OWEN had fallen as to the geological antiquity of the human skeleton that was found in the bottom part of the Alluvium, and which is by no means of Palæolithic age (for reference to SIR R. OWEN's work, see p. 470).

I carefully noted these sections in January and February 1885, when they were in good order in many parts, and also saw them later on. From my notes, and from the many borings made, the following general section (on the whole fairly regular) was made out, from which it will be seen that the alluvium here consists of 8 more or less distinct beds, being more complicated therefore than is the case higher up the river. The numbers affixed to the beds are the same as those used in figs. 99–102:—

- |                                       |  |  |
|---------------------------------------|--|--|
| Alluvium                              | {  | 1. Marsh-clay, the top part discoloured to a brownish tint, by weathering (1'), the rest bluish-grey; up to 15 feet.   |
|                                       |  | 2. Thin peat; up to 1½ feet: sometimes absent.   |
|                                       |  | 3. Light-grey marsh-clay and silt; up to 6 or 7 feet.  |
|                                       |  | 4. Thick reedy peat; generally 4 or 5 feet, but up to 6 feet: constant, except for a few narrow channels, cut through to the underlying bed and filled with marsh-clay (see p. 469). |
|                                       |  | 5. Light-grey marsh-clay; up to 12 feet.   |
|                                       |  | 6. Thin woody peat - } Sometimes absent, from 8 rising up  |
|                                       |  | 7. Light-grey marsh-clay } high.   |
|                                       |  | 8. Light-grey sand; up to 15 feet: sometimes absent.   |
| 9. River Drift.                       | Gravel and sand, rarely seen. Inferred to be from 10 to 20 feet thick. |  |
| 10. Chalk, rarely touched in borings. |  |  |

\* *Archæological Journal*, 1885.

† *Proc. Geol. Assoc.*, vol. viii., no. 7, pp. 392–396 (1884), and *Trans. Essex Field Club*, vol. iv., pt. 9, pp. 135–148. (1885.)

Figure 99. Section through the Tilbury Docks (middle part) from N.N.W. to S.S.E.

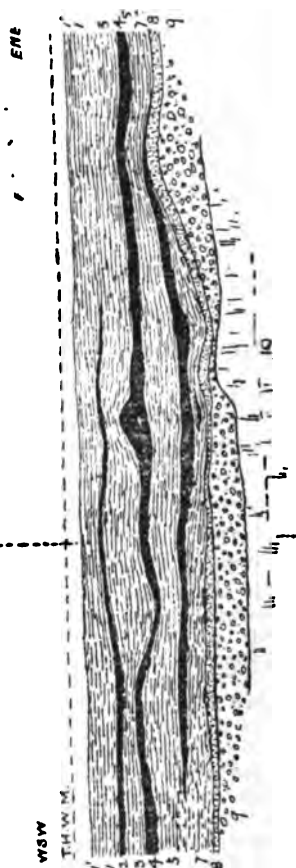
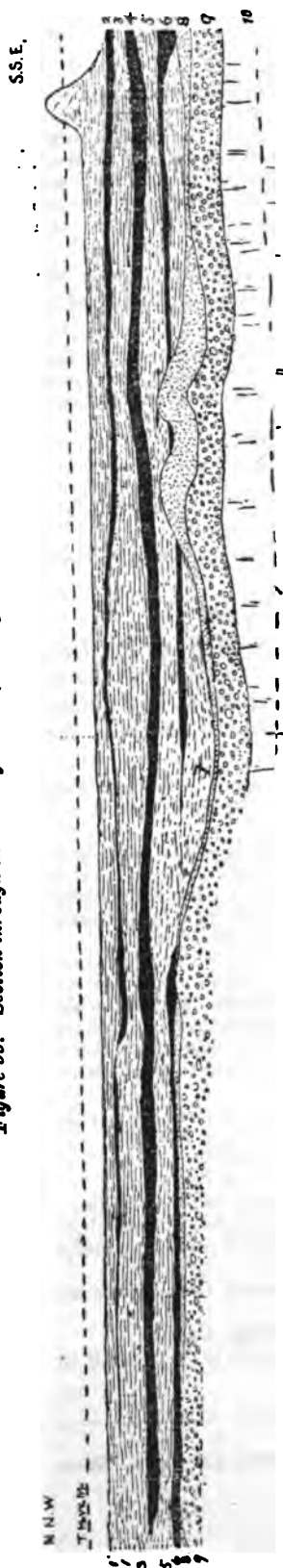


Figure 100. Section along the Southern Side of the Main Basin, Tilbury Docks.

The vertical broken line shows where the two sections cross.

- 1'. Brown (discoloured) marab-clay.  
 Alluvium. { 1, 3, 5, 7. Bluish-grey marab-clay.  
                   2, 4, 6. Peat.  
 8. Sand, in places loamy.  
 9. River Drift. Gravel.  
 10. Chalk.

Of course in the absence of a peat-bed it is impossible to distinguish the grey marsh-clays above and below its horizon, which come together. Moreover there were sometimes peaty patches in the clay, in which indeed there was evidence of plant-life in the presence of rootlets. The whole deposit is merely an alternation of marsh-clay and peat, mostly with a base of sand, and it is thicker than in tracts higher up the river, as would be expected. The thicknesses given were actually seen, and might be increased from the records of the borings.

The increase of thickness, as compared with the alluvium of the Albert Docks and of the Millwall Docks, seems to be not so much an increase in thickness of any bed, but to result rather from the coming in of fresh beds, the Tilbury section showing more alternations of clay and peat than do the others.

Indeed the section at the Albert Docks showed a far greater thickness of a peat-bed than occurred anywhere at Tilbury: whether this thick peat-bed is the same as the main peat of Tilbury (4) one cannot say; but from its being very woody, sometimes indeed crowded with timber (see p. 462), one would infer not, and would class it rather with the lower thin peat (6), which is of like character.

The figures (99, 100) have been drawn from the measurements given by borings on or near to the lines along which they are taken, with additions from actual inspection. The data were originally put together on a much larger scale, and two of the drawings thus made have been reduced by MR. GOODCHILD.

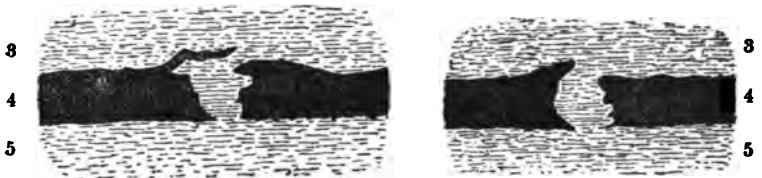
MR. SPURRELL saw here "Roman tiles and pottery, with bones and food refuse, oyster and snail shells, tiles, and flint-blocks . . . in the fine alluvial grey clay, but on a mossy and grass-grown surface which could not have been unlike the surface of the marsh there at present. This layer was 7 feet below the surface. The area covered with remains was about 40 yards square, but there were signs of a much wider spread."\*

Having described the general character of the section one may now notice peculiarities that were shown at various parts.

When the steam-navvy was at work sulphuretted hydrogen was often given off, apparently from the main peat-bed chiefly.

In the middle part of the chief dock the lower surface of the thick peat was seen to be even, though slightly waved, and sharply defined, whilst the upper surface was irregular. Here too a remarkable gap in this peat occurred, as shown in fig. 101, and I was told that many such had been found.

*Figures 101, 102. Sections across Channels through the Main Peat-bed, Tilbury Docks.*



3 and 5. Marsh-clay.

4. Peat.

In the Western Branch Dock the main peat occurred evenly throughout the section.

The Middle Branch Dock was less advanced, except at the entrance; but the reedy character of the main peat was well shown, the bed being full of flat thin yellowish leaves.

In the Eastern Branch Dock this peat was fairly even, but with an irregular bulbous clay-channel through it, as in fig. 102. The reeds were chiefly in a layer some 3 feet down in the peat, and some at the top, whilst the rest was more earthy. Southward this bed rose a little, and then seemed to be cut off rather suddenly.

\* *Archaeological Journal*, 1883.

Along the middle part of the Tidal Basin, the peat, 4 feet thick, underlain and overlain by thick marsh-clay, was slightly waved, and full of rootlets or twigs. It was in this basin that the human skeleton was found, at a depth of about 34½ feet, in the sand, No. 8 of the general section: this discovery has been described by SIR R. OWEN.\*

MR. BRISTOW notes that "at the Old Battery, S.E. of East Tilbury Church, strong black clay, 3 feet thick, was found over dark sand, full of water at a depth of 6 or 7 feet."

#### *Southern Side, from Gravesend to the Medway.*

From below Gravesend to north of Allhallows there is a long broad strip of marshland, indented by various small streams; but no sections were seen other than along ditches.

The following account of the beds passed through on the foreshore in making the Terrace Pier, Gravesend, is from a paper by MR. J. B. REDMAN†. "The foreshore of the river is composed of mud, which varies in depth according to the slope of the shore; it also varies in consistency, increasing in tenacity according to its depth, until where it overlies the silt and sand, it acquires the nature of clay; the flint and gravel bed, overlying the chalk, varies in depth from 9 feet to 14 feet below the level of low-water spring tides, and above the flints is a stratum of yellow loamy sand from 2 feet to 4 feet in thickness, over which there has generally been found about 2 feet of silt and brown sand, upon which lies the alluvial clay deposit."

The alluvium eastward of the Hundred of Hoo belongs, for the most part at all events, to the Medway rather than to the Thames; but there is nothing to be said of it beyond MR. SPURRELL's remark that "around the shores of Grain . . . Roman potsherds can almost always be found . . . washed out of the mud which constitutes the widespread marsh-land."‡ The fine sections in the Chatham Dockyard Extension are outside our district, and their description falls to another Memoir.

#### VALLEYS OF OTHER STREAMS.

Of the alluvium of the smaller rivers and streams there is little to be said, especially on the south of the Thames, where we have to deal only with short courses. On the north longer courses occur, sometimes indeed to the full extent of the streams, in our district; but sections are rare.

#### *South of the Thames.*

We have here only to deal with the lower parts of the Loddon, the Wandle, and the Darent (with the Cray), all of which have narrow strips of alluvium.

*The Loddon.*—The alluvial tract of Ruscomb Lake, in the south-western corner of Sheet 7 of the map, has been in great part laid bare by drainage. At its western end a freshly-cut ditch showed alluvial clay and sand; the former brown, blue, and black (peaty), with a little blue phosphate of iron; the latter brown, buff, green-grey, and dark green.

*The Wandle.*—Through the kindness of MR. W. S. CRIMP I saw the excavations for the sewer of the Croydon Rural Sanitary Authority (in 1880),

\* *Proc. R. Soc.*, vol. xxxvi. p. 186 (1883), and more fully in his "Antiquity of Man as deduced from the Discovery of a Human Skeleton . . . at Tilbury . . ." 8° London, 1884.

† *Proc. Inst. Civ. Eng.*, vol. iv. p. 229. (1845).

‡ *Archæological Journal*, 1885.

along the road eastward and north-eastward of Ravensbury Mills, Lower Mitcham. Here the alluvium reaches rather farther from the river than is shown on the map, to just northward of the road, along which the following sections were seen, by the entrance to the Floor Cloth Manufactory (and nearly a quarter of a mile westward of the Railway Station).

Black peaty earth, with a marly layer near the base; over 6 feet.

Sandy silt, seen to a depth of a foot.

Along the road westward there was alluvium at top, wherever the section could be seen, and just eastward of the Ravenspring Mineral Water Works, the section below:—

Made ground.

Alluvium { Peaty earth.  
Sandy silt, scooping into the gravel, and then thinning out eastward.

River Drift. Gravel.

In describing the Sewerage Works at Mitcham MR. CRIMP remarked that in the area in question, which is 28 acres in extent, "the character of this land varies considerably, being composed of alluvial deposit overlaying the London clay, the constituents of the deposits being beds of gravel and sand, marsh, clay, and peat. The depth from the surface of the ground to the London clay varies from 3 to 17 feet."\*

#### *North of the Thames, above and in London.*

The Loudwater, the Colne, and the tributaries of the latter have narrow strips of Alluvium along the greater part of their courses; but in the case of the Colne only does this ever reach a breadth of half a mile, often indeed being less than a quarter of a mile.

MR. USSHER notes that "south of Sarratt's Bottom the alluvium of the Chess consists of peat mixed with chalk-rubble."

The Brent has in places formed a stiff clay-alluvium, from the wash of the London Clay, and much like that formation.

In London itself there are some patches of alluvial deposits, which, though having no connexion with any existing stream, may have been formed by springs issuing from the gravel, and which perhaps once caused feeders to the Fleet. These will now be noticed.

In January 1887 I saw an interesting exposure in Finsbury Crescent, during the underpinning of the theatre of the London Institution. The site was originally marshy fields, with a pond, and underneath the building black boggy earth with stones was found, marl being said to occur beneath. Each pier was supported by sets of 9 piles, made of elms, said to have been cut on the spot, about 8 feet long, with pointed tops, on which rested cross-pieces. The tops of the piles had decayed, and the cross-pieces were consequently left almost without support. This work has of course been replaced by brickwork.

GEN. PITT-RIVERS (then COL. LANE FOX) has described some excavations for a foundation near London Wall,† giving the following general section:—

Superficial earth [made ground, &c.]; 9½–12 feet.

Peat. At one place with a 6-inch layer of blue sand, underlain by a 4-inch layer of calcareous matter near the middle, and at another part a like calcareous layer at the bottom. With "kitchen-middens," wooden piles, bones, Roman pottery, &c., 7–9 feet.

Gravel, at a depth of 17 feet towards the north, inclining to 22 feet towards the south.

The author says:—"By information which I have received . . . it appears that throughout the whole tract of ground between this and the Thames

\* *Iron*, vol. xv., no. 366, p. 44. (1880.)

† *Anthrop. Rev.*, no. 17, pp. lxxi., etc. (1866.)

similar remains of peat, piles, bones, and Roman pottery have been found. At the new Auction Mart north of the Bank piles have been found connected by camp-sheathings, . . . that is, by planks joining them horizontally. At the Mansion House, and in the line of the old Wall Brook, piles, peat, and Roman pottery were discovered."

"The chief region of Roman remains [at London Wall] is within 2 to 3 feet of the gravel."

### *Valley of the Lea.*

As this valley is distinguished from the valleys of other tributaries of the Thames by containing a long and broad sheet of River Drift, so also is it marked, though to a less extent, by the breadth of its marshland, which is rarely less than half a mile, and, at Hoddesdon, reaches to a mile across.

In 1863 some good sections of alluvium were laid open in the new reservoir of the East London Water Company in Walthamstow Marsh. In the most southerly reservoir the following beds occurred, at different parts:—A foot or more of brown clay over gravel; blackish peaty clay over gravel; six inches or more of shell marl over peaty clay over sandy gravel; and sometimes a little shell-marl below, or in the midst of, the clay. I was told by MR. MAINE, the foreman of the works, that as much as five feet of shell-marl had been found, and (near the northern end of the north-eastern reservoir) as much as from 8 to 10 feet of peat; and that outside the reservoirs they had sunk through the gravel, which was from 12 to 30 feet thick, to the London Clay.

In 1869 DR. H. WOODWARD described later sections, shown in excavations here, and the following notes are taken from his paper.\*

"The depth penetrated over the whole area of the floor of the Reservoirs probably nowhere exceeds . . . 10 feet, but the trenches made for the "puddle-walls" in the centre of the artificial embankments which enclose the Reservoirs, go down to a depth of 20–24 feet"

"The beds above the gravel which forms the floor . . . vary in thickness and extent over the whole area. Thus, the shell-marl or deposit consisting of a vast accumulation of Land and Freshwater shells . . . varies in thickness from two inches to three feet, and occupies basins or depressions in the underlying clay or gravel."

Three detailed sections are given, much as follows, the words in square brackets being added by me.

Section at the south-eastern corner of the Eastern Reservoir:—

Soil; 12 inches.

[Alluvium]	{	Clayey loam; 18 inches.	
		White shell-marl; 10 inches.	
[River Drift]	{	White-coated subangular gravel, encrusted from above; 18 inches.	
		Rounded and subangular gravel, stained with iron-oxide; not bottomed, but more than 10 feet found (in a hole) with much water.	

Section at the south-western corner of the Western Reservoir:—

		FEET.
Mould	-	1
[Alluvium]	{ Stiff, brown clay	2
	{ Shell-marl and marly clay	1 to 3
	{ Stiff, dark clay, with wood	1½
	{ Peat	2
[River Drift]	{ Gravel, stained black from the peat	½
	{ Clean, red gravel.	

\* *Geol. Mag.*, vol. vi. pp. 385–388. Reproduced in *Trans. Essex Field Club*, vol. iii., pt. 7, pp. 3–7. (1883.)

Section in the Eastern Reservoir, near the embankment between it and the Western Reservoir:—

		FEET.
Soil	-	1½
[Alluvium]	{ Stiff clayey loam	1½
	{ Very compact, black peat	3
	{ Shell-marl	1
[River Drift]	{ White-coated, subangular gravel	1
	{ Clean, red gravel.	

"The beds above the shell-marl (and, in some parts of the area, those below it), contain abundant remains of forest vegetation. Large areas of the upper loamy and peaty beds, where exposed in the course of the works by the removal of the more superficial layers, exhibiting the ancient remains of trees with their spreading roots still in situ, but in most instances converted into lignite and coated with bog-iron-ore. Hazel nuts are abundant, and we were able to detect evidence of the Oak and the Alder. . . ."

"The Shell-bed, on the Eastern and Northern sides of the area exposed, exhibited many cases of oblique lamination, indicative of currents and a winding rivercourse. Most of the bivalve shells have their valves united, and the *Uniones* reposing [repose] in their natural position as in life, while the operculum remains in the aperture of many of the *Paludinae*."

An examination of a small quantity of the shell-marl yielded the species of land and freshwater shells given in the list, p. 477, whilst the Mammalia came from the peat and the shell-marl.

A few bronze weapons, an iron sword (late Celtic), various other human relics and "late Celtic" pots were found.

The paper concludes as follows:—"From the broad tract of the Lea Valley occupied by the Freshwater Shell-bed, and also from the abundance of Drift-wood, together with remains of the Beaver, it is quite possible that we may have here preserved to us the evidences of an old forest-tract flooded by Beaver dams, a condition of things which is sure to arise wherever the Beaver makes his habitation."

We have also an older record of sections lower down the valley, as follows:—

"In excavating a canal and reservoir in Hackney Marsh, for the use of the East London Water Works Company, a little to the north of Temple Mill, between those mills and Lea Bridge, a *boat* was discovered at a depth of about four feet below the surface of the marsh, which was embedded in a stratum of black clay with shells intermixed; this stratum continues of the same quality to the depth of five feet: above the *boat* there was a stratum of yellow clay about three feet deep. . . . Its dimensions were twenty feet from head to stern, six feet wide, and eighteen inches deep, and [it] was what is termed *clinker-built*, the joints being made tight with a cement in which cow-hair was used."

"The antler of a deer was also found at the depth of six feet below the surface of the marsh, embedded in a mixture of peat, shells, and some white substance like decomposed bones."

"Throughout the marshes, in excavating between twenty and thirty acres in extent, under the surface yellow and blue clay and then gravel was found with scarcely any peat or variation."\*

Figure 103 has been reduced, by MR. GOODCHILD, from a tracing that I made of a plate in the book above-quoted. Details at the spots numbered on the sections are given, from which the following account is compiled.

Along the section A. B. parallel with the river: 1, 2, and 3.

		Ft.	Ft.	Ft.
[Alluvium]	{ Yellow clay	2½	4½	4½
	{ Blue clay (muddy clay with shells in 3)	1½	1	3
	{ Peat	1½	1½	—
[River Drift.]	Gravel	2	—	—

\* DR. W. ROBINSON'S "History of Hackney, vol. i., 1842, pp. 24, 25.



4 and 5. Sand, clay, and shells occur beneath the yellow clay, in two beds in 5, divided by mud.

6, 7, 8 and 9—

		Fr.	Fr.	Fr.	Fr.
[Alluvium]	Yellow clay - -	4½	6	3½	2
	Mud, with shells in 6 -	1	—	2½	—
[River Drift.]	Gravel - -	1½	1½	1½	4

Along the section C. D. across the river: 1 and 2. Alluvium not penetrated. Yellow clay at top. Shells found in sand and in clay.

3 and 4—

		Fr.	Fr.
[Alluvium]	Yellow clay -	4	2½
	Clay and Gravel	—	1
	Sand -	½	1
	Light-blue clay	1½	—
[River Drift.]	Clay and peat -	1	1
	Gravel -	1	3

5 and 6—

Yellow clay, 2½ and 2 feet.

Gravel (with a little sand in 5) 6, and 7 feet.

7. Only a foot of soil over gravel, to 5½ feet.

MR. WORTHINGTON SMITH has recorded the finding of "three superb wholly-polished flint celts . . . just under [?] the alluvium at Temple Mills, near Stratford . . . The celts were found side by side and touching each other; they could not have got into such a position by accident, but were clearly so placed by their Neolithic owner."\*

#### *North of the Thames below the Lea.*

MR. H. B. WOODWARD notes that "the alluvium of the Roding does little more than fill up the bends of the stream. The deposit is generally a clay, redeposited London Clay in fact. The river however is so inaccurately laid down on the old Ordnance map (1, N.W.) that it has been impossible to draw very satisfactory lines." A section at Ilford has been given on p. 410.

The Bourne and the Ingrebourne have but very narrow strips a few miles up their course. Along the Mardyke however there is a broader spread, forming Bulphan and Orsett Fens, in the London Clay tract; whilst below, where the Lower London Tertiaries and the Chalk crop out, the marshland narrows.

MR. WOODWARD records that "at Bridgemarsh Island, in the Crouch, alluvial clay has been worked in a large brickyard," and of the Chelmer valley he says that "the stream floods the ground at times near Cowbridge, eastward of Mountnessing, and between Buttsbury and Ingatestone the road is occasionally impassable. Below Chelmsford the alluvium spreads out and forms fine meadow-land."

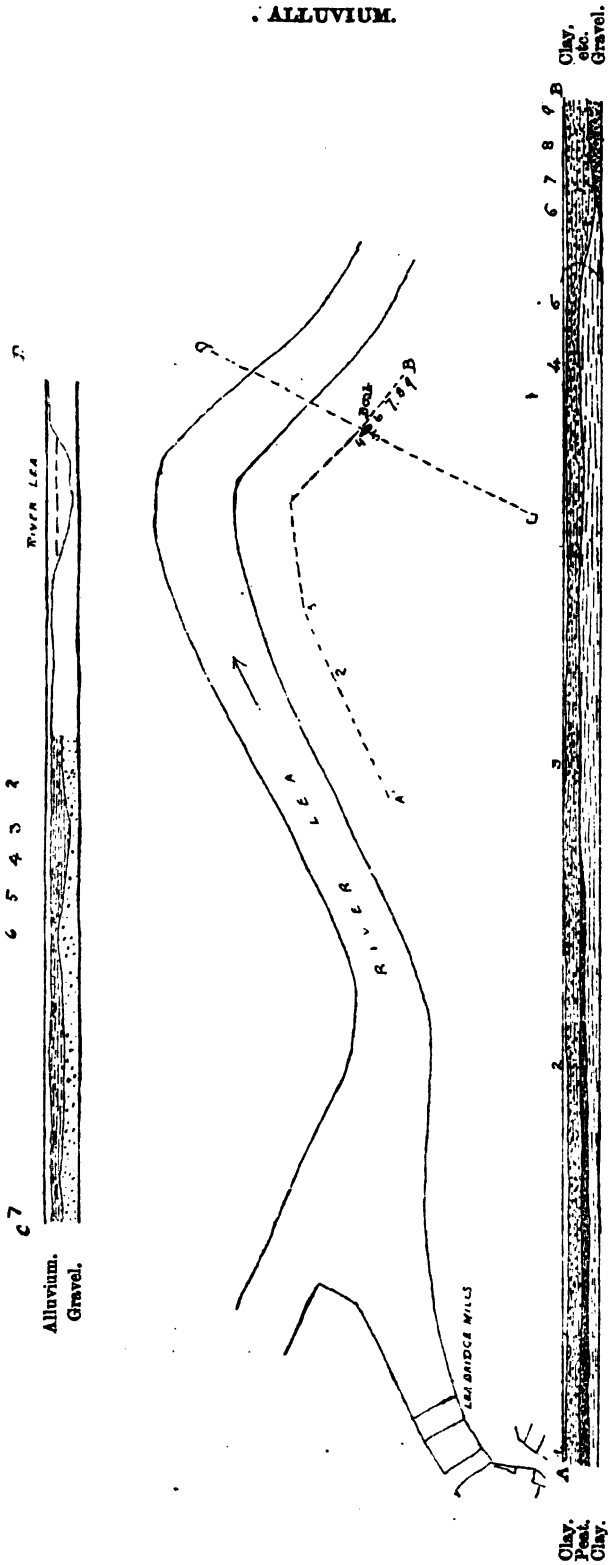
Judging by a paper on "Recent Shell Deposits"† there may be some alluvium up the tributary-valley of the Cann; but, as far as I can make out from the description, the site where the sixty odd species of shells were found, near Chignal St. James, is just outside our district. The deposit consists of peaty earth, peat, and clay, apparently with tufa, and is described as occurring in two patches.

Of the broad spread of East Essex Alluvium, through which the Crouch flows to the sea, and which, on the south of that river, is cut into a set of islands, by the tributary Roach and by its

\* *Trans. Essex Field Club*, vol. iii., pt. 7, p. 147, and fig. 24. (1883.)

† *Natural History Journal*, vol. iii., no. 1. pt. i. (1879.)

Figure 103. Sections in the Marshes of the Lea, below Lea Bridge.



Reduced from a Plate in Dr. W. ROBINSON'S History of Hackney, vol. 1, 1842.

The numbers mark the spots where detailed sections are given. The firm lines at the top of each section apparently represent levels.

various creeks, it is open to question whether it does not really belong to the Thames.

In describing the River Drift we have seen that the old Thames, of that period, seems to have turned northward, after receiving the Medway, and it is most likely that the modern river has followed the same course, here, as elsewhere.

If so a somewhat surprising conclusion follows: for we must then infer that, at the time when this, the broadest tract of Alluvium in our district, was formed, the valley of our chief river must have reached many miles eastward of Foulness and of the neighbouring marshes, and that fairly high land must have extended north-eastward from Sheppey, far out into what is now sea, so that the Crouch was then only a tributary of the Thames. It would follow therefore that since this late geologic period, or in Neolithic and later times, very many miles have been lost from our sea-board in eastern Essex, and in northern Kent; to such an extent indeed as to destroy the whole of the right side of the broad valley of the Thames, and to leave only the alluvium of the left side of the valley-bottom as a sign of the former course of the river.

Perhaps the deep channels that now occur north-eastward from the Nore are the direct descendants of the former extension of the estuary of the modern Thames.

#### FOSSILS.

It is rarely that sections of any note are to be seen in alluvial deposits, and when such sections occur they are of a kind soon hidden, in excavations for docks, etc. It is not often therefore that there is a chance for collecting fossils. The chief information we have in this matter comes from the valley of the Lea, where the East London Water Company has made large excavations for reservoirs, from which luckily collections have been made.

The species are all recent, and those of the Mollusca are such as live now in our streams and ponds, with a liberal contribution from the land.

In the following list, which has been corrected by MR. G. SHARMAN and MR. E. T. NEWTON, the localities are marked as follows:—

- 1 = *Southwark*. South Eastern Railway, eastward of Blackfriars Road. On the authority of MR. C. J. A. MEYER, *Proc. Geol. Assoc.*, vol. i., no. 9, p. 266. (1863.)
- 2 = *Walthamstow*. Reservoirs of the East London Water Company. On the authority of DR. H. WOODWARD, *Geol. Mag.*, vol. vi. p. 387. (1869.)
- 3 = *Near Hackney*. Works of the East London Water Company. On the authority of MR. J. E. GREENHILL, "Prehistoric Hackney," Paper ii., pp. 2-4. (1883.)

#### VERTEBRATA.

<i>Alces machlis</i> , <i>Ogilby</i> ( <i>Cervus alces</i> , <i>Linn.</i> )	-	-	-	-	2	3
<i>Arvicola amphibius</i> , <i>Linn.</i>	-	-	-	-	2	3
<i>Bison bonasus</i> , <i>Linn.</i> var. <i>priscus</i> , <i>Boj.</i>	-	-	-	-	-	3
<i>Bos taurus</i> , <i>Linn.</i> , var. <i>longifrons</i> , <i>Owen</i> [= <i>frontosus Nilss.</i> ]	-	-	-	-	2	3
"    "    " <i>primigenius</i> , <i>Boj.</i>	-	-	-	-	-	3
<i>Canis lupus</i> , <i>Linn.</i>	-	-	-	-	2	3
" <i>vulpes</i> , <i>Linn.</i>	-	-	-	-	2	3
" <i>sp.</i> [dog]	-	-	-	-	-	3

<i>Capra hircus</i> , Linn.	-	-	-	-	-	1	2	3
<i>Castor fiber</i> , Linn. [= <i>europæus</i> , Owen]	-	-	-	-	-	-	2	3
<i>Cervus</i> ( <i>Capreolus</i> ) <i>capra</i> , Gray	-	-	-	-	-	-	2	3
„ <i>dama</i> , Linn.	-	-	-	-	-	-	2	3
„ <i>elaphus</i> , Linn.	-	-	-	-	-	-	2	
„ <i>giganteus</i> , Blum. [= <i>Megaceros hibernicus</i> ]	-	-	-	-	-	-	-	3
„ ( <i>Rangifer</i> ) <i>tarandus</i> , Linn.	-	-	-	-	-	-	2	3
<i>Equus caballus</i> , Linn.	-	-	-	-	-	-	2	3
<i>Ovis aries</i> , Linn.	-	-	-	-	-	-	-	3
<i>Sus scrofa</i> , Linn.	-	-	-	-	-	1	2	3

<i>Haliæetus pelagicus</i> , Call. [probably <i>H. albicillus</i> ]	-	-	-	-	-	-	2	
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Fish vertebræ	-	-	-	-	-	-	-	2
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## MOLLUSCA.

## Gasteropoda.

<i>Ancylus fluviatilis</i> , Müll.	-	-	-	-	-	-	2	3
„ <i>lacustris</i> , Linn. [= <i>oblongus</i> , F. and H.]	-	-	-	-	-	1	-	
<i>Bythinia</i> <i>Leachii</i> , Shepp. [= <i>ventricosa</i> , Gray]	-	-	-	-	-	-	2	3
„ <i>tentaculata</i> , Linn.	-	-	-	-	-	1	2	3
<i>Carychium minimum</i> , Müll.	-	-	-	-	-	1	-	
<i>Clausilia biplicata</i> , Mont.	-	-	-	-	-	-	-	3
„ <i>laminata</i> , Mont. [= <i>bidens</i> , Müll.]	-	-	-	-	-	-	2	
„ <i>p</i> sp.	-	-	-	-	-	1	-	
<i>Cochlicopa</i> [ <i>Zua</i> ] <i>lubrica</i> , Müll.	-	-	-	-	-	1	2	3
<i>Helix aculeata</i> , Müll.	-	-	-	-	-	-	-	3
„ <i>arbustorum</i> , Linn.	-	-	-	-	-	-	2	3
„ <i>caperata</i> , Mont.	-	-	-	-	-	-	2	3
„ <i>ericetorum</i> , Müll.	-	-	-	-	-	-	2	3
„ <i>hispidia</i> , Linn.	-	-	-	-	-	1	2	3
„ <i>hortensis</i> , Müll.	-	-	-	-	-	-	2	3
„ <i>nemoralis</i> , Linn.	-	-	-	-	-	1	2	3
„ <i>pulchella</i> , Müll.	-	-	-	-	-	1	-	3
„ <i>rotundata</i> , Müll.	-	-	-	-	-	1	-	
<i>Hyalinia</i> [ <i>Zonites</i> ] <i>crystallina</i> , Müll.	-	-	-	-	-	1	-	3
„ „ <i>nitidula</i> , Drap.	-	-	-	-	-	-	-	3
„ „ <i>radiatula</i> , Alder.	-	-	-	-	-	-	-	3
<i>Limnæa auricularia</i> , Linn.	-	-	-	-	-	1	2	3
„ <i>glabra</i> , Müll.	-	-	-	-	-	-	-	3
„ <i>palustris</i> , Müll.	-	-	-	-	-	1	2	3
„ <i>peregra</i> , Müll.	-	-	-	-	-	1	2	3
„ <i>stagnalis</i> , Linn.	-	-	-	-	-	1	2	3
„ <i>truncatula</i> , Müll.	-	-	-	-	-	1	2	3
<i>Neritina fluviatilis</i> , Linn.	-	-	-	-	-	1	2	3
<i>Physa fontinalis</i> , Linn. [= <i>fluviatilis</i> ]	-	-	-	-	-	1	-	3
„ <i>hypnorum</i> , Linn.	-	-	-	-	-	1	-	3
<i>Planorbis albus</i> , Müll.	-	-	-	-	-	1	-	
„ <i>carinatus</i> , Müll.	-	-	-	-	-	1	2	3
„ <i>complanatus</i> , Linn. [= <i>marginatus</i> , Drap.]	-	-	-	-	-	1	-	3
„ <i>corneus</i> , Linn.	-	-	-	-	-	1	2	3
„ <i>contortus</i> , Linn.	-	-	-	-	-	1	-	
„ <i>lineatus</i> , Walker [= <i>lacustris</i> , F. and H.]	-	-	-	-	-	1	-	
„ <i>nautilus</i> , Linn.	-	-	-	-	-	1	-	
„ <i>spirobis</i> , Linn.	-	-	-	-	-	1	-	3
„ <i>vortex</i> , Linn.	-	-	-	-	-	1	2	3
<i>Pupa marginata</i> , Drap. [= <i>muscorum</i> ]	-	-	-	-	-	-	-	3
„ <i>umbilicata</i> , Drap.	-	-	-	-	-	-	-	3
„ <i>p</i> sp.	-	-	-	-	-	1	-	
<i>Succinea elegans</i> , Risso [= <i>gracilis</i> and <i>Pfeifferi</i> ]	-	-	-	-	-	1	-	3
„ <i>putris</i> , Linn.	-	-	-	-	-	1	2	3

<i>Valvata cristata</i> , Müll. -	-	-	-	-	-	1		
„ <i>piscinalis</i> , Müll.	-	-	-	-	-	1	2	3

*Lamellibranchiata.*

<i>Pisidium amnicum</i> , Müll.	-	-	-	-	-	1	2	3
<i>Sphaerium</i> [= <i>Cyclas</i> ] <i>corneum</i> , Linn.	-	-	-	-	-	1	2	3
„ <i>rivicola</i> , Leach	-	-	-	-	-	1		
<i>Unio pictorum</i> , Linn.	-	-	-	-	-	—	2	3
„ <i>tumidus</i> , Philipps.	-	-	-	-	-	—	2	3
„ or <i>Anodon</i>	-	-	-	-	-	1		

## MISCELLANEOUS ACCUMULATIONS.

*Shore-deposits.*

In the lower part of the estuary of the Thames the water has sometimes deposited, in more or less favourable spots, a mass of sea-shells, sand, and shingle, beached up over or against the alluvial clay, etc.

Shells were seen at the eastern side of St. Mary's Bay, northward of Hoo St. Mary, and further east, from Dagnam Salting to Brick-yard Point, Allhallows, shells sand and shingle occur along the shore.

Southward of where Yantlet Island is marked, on the old one-inch Ordnance Map (1, S.E.), a curved bar of shells, bedded, and overlying marsh-clay, was mapped when the Geological Survey of that part was made.

Eastward from Yantlet Creek there were scattered shells, culminating, before reaching the next point, in a shell-beach. Facing the Isle of Grain there were again only patches; but, on turning round to the estuary of the Medway, the shore was fringed with shells, shingle and sand, up to Cockle-shell Hard.

Crossing to the Essex side of the Thames, Mr. BRISTOW noted that "the small patch of alluvium by the 'Crow Stone,' between Leigh and Southend, is separated from the beach by a strip of shells, shingle and blown sand, about a chain wide."

From Lower Southend to Camper House there is also a deposit of sand and shells, and again further eastward.

MR. WOODWARD notes that "Shoebury Common is on a recent beach-deposit or natural embankment, of sand and shells, containing the shells of the common cockle, mussel and periwinkle." This mass forms Shoebury Ness, and beyond this, north-eastward and northward, "the coast presents, at low tide, a vast expanse of mud and sand, an estuarine alluvium;" but evidence of an older shore-line, some way inland, is given by the patches of shelly sand and shingle that have been mapped in the southern part of Foulness Island, and still more by the almost unbroken stretch of the like through Burnham, Southminster, and Dengie Marshes, from Hollywell northward to beyond Grange, with its continuation, in five isolated patches, through Tillingham and Bradwell Marshes.

*Greywethers and Pudding-stones.*

It will be well to notice here the frequent occurrence of blocks of hard sandstone and of conglomerate on the surface in the Chalk and Tertiary districts.

The pudding-stones consist merely of flint-pebbles, and sometimes a few subangular flints, in a matrix of greywether-sandstone. They are often remarkable for their even jointing, the joint-planes running indifferently through matrix and pebbles, and giving a flat face. In former times querns, or millstones worked by hand, were made from them; the unequal wearing away of the harder pebbles and the softer matrix well fitting them for that use. One of these querns may be seen in the Museum at Jermyn

Street, where there are also specimens of the greywether sandstone and of the conglomerate.\*

With PROF. PRESTWICH, who has treated of the origin of these blocks in great detail,† one may conclude that in this district they have been derived in great part from the Woolwich and Reading Beds; although there is reason to think that at the western end of the London Basin, where they are present in greater number, the origin of the greywethers may be traced to the Bagshot Sands.‡

Sandstone however is rarely to be seen in place in the Reading Beds, and I know of but two places in our district where it has been observed, near Amersham and Chesham (see pp. 192, 194), and in both cases the bed is too thin to have yielded any of the large blocks so often found. Near Aldenham, however, there seems to be a large mass of hard, jointed pudding-stone in place (see p. 200).

PROF. PRESTWICH has noted the fact that it is in Hertfordshire, where the sands of the Reading Beds are often charged with flint-pebbles, that the blocks of conglomerate are most common. Hence the name "Hertfordshire pudding-stone."

It is likely, however, that in this more central part of the London Basin other formations have also yielded greywethers. The basement-bed of the London Clay often contains a thin bed of sandstone; mostly however with fossils, which, on the contrary, are not found in the greywethers; and in the Wargrave outlier I saw a bed that might well have been the origin of some of the smaller blocks.

The fact that greywethers are found over the London Clay country, and far from the outcrop of the Reading Beds, would accord with their derivation from a formation above, rather than from one below, the London Clay. One is led to think therefore that these loose blocks may have come from various beds, and that in this district their origin may be traced not only to the Reading Beds, but also, perhaps, to a slight extent, to the basement-bed of the London Clay and certainly to the Bagshot Sands, most likely however to a higher division than any occurring in our district.

As a rule these stones show no sign of having been carried any distance, and it would seem that they have been quietly let down during the slow denudation and removal of the softer materials of the beds of which they once formed part.

Speaking of the Wycombe district, PROF. BUCKLAND said: "Large blocks of a coarse variety of . . . pudding-stone are not uncommon on the surface of the chalk . . . at Bradenham,"§ and MR. JUKES-BROWNE notes that "in the short side-valley in which Bradenham stands blocks of pudding-stone are abundant, and pieces have been set up round the Green. Above the church, and extending up to the head of the valley, is a rough field, strewn with large blocks of this conglomerate; so large and numerous are they that one is led to believe that a continuous bed of the rock must have once existed on the hills above. They seem to be piled one on the top of the other, and

\* See the Catalogue of Rock Specimens. Ed. 3, p. 106.

† *Quart. Journ. Geol. Soc.*, vol. x, pp. 123-130. (1854.)

‡ *Ibid.*, vol. xviii, p. 271. (1862.)

§ *Trans. Geol. Soc.*, vol. iv, p. 301. 1817.]

many only just peep out of the grassy mounds which have grown over them. The largest block I saw measured  $11 \times 7$  feet and was 3 feet thick in its deepest part: another close by measured  $9 \times 7 \times 3$  feet."

The presence of numbers of greywethers at other places near Wycombe has already been noticed (pp. 288, 289).

MR. WORTHINGTON SMITH has noted the occurrence of large block of sandstone in a disused gravel-pit on the western side of Orsett Heath, and characterised it as the largest he has "heard of as occurring in the gravels near London." The Rev. J. W. KENWORTHY, at the same time,\* described a block of conglomerate (pudding-stone) that stands on the road to Bulford, "against a blacksmith's shop, about half a mile from White Notley Village," adding that it is the only large block of the sort in the neighbourhood, and giving the following particulars of stones in Buckinghamshire. "In Chesham Churchyard . . . there are several of the same kind, and one is ten or twelve feet across," and at "Denner Hill (see p. 289) . . . there are masses of conglomerate and rough reddish sandstone . . . weighing a hundred tons or more."

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\* *Essex Naturalist*, no. 1, p. 8. (1887.)

## CHAPTER 27. PHYSICAL GEOLOGY.

## DISTURBANCES.

*General.*

THE London Basin is perhaps the least disturbed of all the great geological tracts of our island, and yet its existence is in great measure owing to disturbance, the general inward dip and the troughed arrangement of the beds having preserved them from denudation; whilst they have been carried off from the flat dome of the Weald.

The chief disturbance is that which has thrown the beds into the form called "a basin," which in this case is a very shallow trough, narrowing westward and cut off by the sea on the east. This has resulted in a general south-easterly dip at a very low angle on the northern side of the basin, and on the southern in a general northerly dip at a rather higher angle, sometimes indeed much higher.

The trough of the London Basin must not however be viewed by itself as an independent disturbance, for it is but a part of the gentle wave of which the trough of the Hampshire Basin on the south and south-west is another part, and also the saddle-back of the Weald between the two.

That the two troughs have been formed since the deposition of the Tertiary Beds which fill them is clear, those beds having originally been deposited in a more or less level manner, and most of them having stretched across from basin to basin. Nevertheless there is evidence, from the irregularity with which parts of the Lower London Tertiaries occur over the Chalk of Kent and Surrey, that some elevation existed in what is now the Weald during the deposition of those beds, and that to some extent the Chalk was planed down over the Wealden area in that early period. The great difference in the structure of the Lower London Tertiaries on the north of the Weald (in Kent and in eastern Surrey) and on the south (in the Hampshire Basin) lends support to this view; the Thanet Beds, and the Oldhaven Beds also (except perhaps for some slight local occurrences, which are yet doubtful) occurring on the north only, whilst the intermediate Woolwich Beds show their estuarine character in one place only on the south, at the Newhaven outlier, many miles east of the main mass, and their marine fossils in East Kent alone, leading one to infer some partial barrier between the two tracts. Moreover the flint-pebbles, both in the Woolwich Beds and in the Blackheath Beds, must have been derived from Chalk. The thicker and deeper-sea deposit of the London Clay most likely spread across uninterruptedly.



Evidence of still older disturbance along the Weald and the London Basin has been given in Chaps. 2 and 3.

The very gentle nature of the trough with which we are dealing may be seen on looking at the Geological Survey Sections across it, which being drawn on the same scale horizontally and vertically, and not, as usual in geological sections, highly exaggerated vertically, show the true dip and relation of the beds. Even these sections may give a slightly exaggerated notion of the dips, for they are drawn on lines selected as passing through the highest points and showing the chief geological features, and so often through parts where comparatively high dips occur; and the same remark applies to the sections across the Weald. Nevertheless all these will at once dispel those ideas of vast foldings of the beds, even still so common, which show themselves in such expressions as the great arch of the Weald, and the deep trough of the London Basin. When compared with the horizontal extent of the latter area the vertical displacement is indeed trifling.

#### *Local.*

Various local disturbances are shown by slight changes of strike, and others by the outcrop of lower beds partly or wholly within the area of higher ones.

Thus at Croydon, where the normal dip is northward, there must be a slight rise in that direction, bringing up the Oldhaven Beds at Selhurst, where we should expect nothing but London Clay.

Near Bromley there is a more important change from the normal northerly dip, bringing up the inlier of the Woolwich Beds and of the Thanet Sand close to that town, and the larger inlier, reaching down to the Chalk, between it and Chislehurst. This elevation is the more marked from the occurrence of outliers of the London Clay at Shooting Common and Crofton Woods, at a lower level than the older beds on the north. The railway-cutting at the south of St. Paul's Cray Common (Fig. 12, p. 137) shows how the slope of the ground in this neighbourhood sometimes almost exactly follows the dip of the beds.

It is perhaps a continuation of this line of disturbance eastward (beyond our district), on a smaller scale, that causes the slight rise of the beds along a line through Hackstable and Clement Street, west of Sutton, and through Green Street Green, east of Darenth.

The regular northern dip is soon regained along this course, and then again lost, from a nearly east and west uprising between Mottingham and Crayford, with apparently some more north and south elevation near the former place, bringing up the Thanet Sand as a small inlier (see Fig. 27, p. 166).

At Eltham the beds again dip northward, but only to rise for a third time from under Shooter's Hill. Their final return to the northerly dip is hidden, partly from their being suddenly cut off by the Thames Valley Fault, and partly by the alluvium, &c. of

the river. I was enabled, however, from well-sections and borings, to trace the boundary-line of the various formations under the flat between Deptford and Rotherhithe.

The small elevation near Dulwich (where it is possible that the outcrop of the Woolwich Beds may be ended off by a fault on the east, near Brockwell Hall) may be connected with this uprise.

Perhaps the low arch of the Chalk cut through by the Thames between Greenhithe, Gravesend, and Cliffe on the south, and Purfleet, Grays, and East Tilbury on the north is a continuation of the Eltham and Crayford line of elevation. This northerly rise has aided in the preservation of the Tertiary beds of the Swanscomb and Gravesend outliers, the former of which has been partially, and the latter perfectly, troughed by it, and of the patch of London Clay west of Higham, as well as of the marked escarpment east of that village, the Tertiary beds between Cooling and Upnor being in a shallow trough.

There are therefore in the Tertiary district south-east of London a set of gentle and roughly parallel waves running nearly east and west, by means of which the lower beds are kept at the surface to a greater extent than would otherwise be the case, for with a steady northerly dip the valley of the Thames would run wholly through London Clay.

The southern part of the Lane End outlier (p. 184) seems to be in a faulted trough, the Reading Beds occurring in the bottom of the hollow.

The inlier of the Reading Beds south of Holyport, near Maidenhead, gives evidence of a slight uprise, but the most marked upheaval of this district is that of the boss of Chalk at Windsor, at a higher level than the surrounding Tertiary beds (see Fig. 28, p. 178). PROF. PRESTWICH is inclined to refer this disturbance to "a line of flexure, running east and west, following nearly the course of the Thames from the Nore to Deptford, and apparently continued thence to beyond Windsor."\* I hardly think however that it can be traced so far eastward, if indeed it runs in that direction at all, but should imagine that it is merely a part of the line of uprise next to be described.

The bay-like outcrop of the Reading Beds at Ruislip Wood, and the inliers at Pinner and Northaw are all owing to some slight local disturbance. It should be noted that those inliers are in a straight line with that of Windsor, as if all were connected; a view which the following remarks by PROF. PRESTWICH support, tending as they do to connect the Northaw and the Pinner elevations;—"As far as the obscure character of the surface and the absence of sections will allow me to judge, a slight disturbance in the form of a ridge or flexure of small elevation runs north-east and south-west through Northaw . . . where it passes thence under the hills between Potter's Bar and Barnet, bringing up there the lower beds of the London Clay in the tunnel on the line of the Great Northern Railway."†

\* Water-bearing Strata around London, p. 40.

† Water-bearing Strata around London, p. 49.

The following facts are worthy of notice. The line of elevation through Northaw, Pinner and Windsor is near and parallel to the escarpment of the Tertiary beds from Twyford, north-westward by Rickmansworth, to Hatfield, beyond and roughly parallel to which are a number of Tertiary outliers, along a line from the hills near Wargrave, through Cookham Dean, the tract between Beaconsfield and Amersham, Sarratt, Abbot's Langley, St. Alban's, and then, beyond our district, by Ayot Green and Datchworth, to a little south of Bennington (Sheet 46).

Each of these three lines is in great part I believe along parts where a slight change of dip takes place. This may have enabled the beds to withstand erosion, better than would else have been the case, along the line of outliers, which are most likely along a slight trough, or along the present escarpment, which may also be partly along another such line; whilst in the case of the inliers, &c. lower beds have not only been brought up, but by that have also been thrown into the form most favourable for erosion.

The line of outliers either merges into that of the escarpment in the tract to the west (Sheet 13) near Reading, or a little westward, in the latter case being continued through the outliers above Caversham and at Tilehurst.

Further out on the wide chalk-tract are traces of another line of outliers through Woodcot Common (above Goring), Nettlebed, Turville Common (all beyond our district and in Sheet 13), and Lane End, which may be continued eastward through Tyler's Hill (above Chesham) and Bennett's End (near Hemel Hempstead), beyond which it may merge into the first line. Westward (in Sheet 13) it seems to continue by Upper Basildon and Yattendon to the main mass.

The valley of the Lea may perhaps be along a line of slight elevation in its southerly course from Broxbourne. There is certainly an uprise near Stratford, where the beds below the London Clay come up to the surface (see p. 168), the base of that clay being also touched, at no great depth, at Leytonstone and at Hackney (see p. 247).

In London the many well-sections (see *post*) show that the level of the top of the Chalk varies. There is an uprise a little north of the Euston Road, as marked in Sheet 79 of the "Horizontal Sections" of the Geological Survey; and this may favour PROF. PRESTWICH'S view of the easterly extension of the Windsor elevation.

#### *Faults.*

Faults of appreciable extent are very uncommon, and it is well that they are, from the great difficulty of tracing them in soft beds. There are however many small shifts in the Chalk, too small to map, and the like sometimes occur in the Tertiary beds, as shown in Figs. 23, 24 (pp. 158, 160). The few faults large enough to be marked on the map have mostly been noticed in the

detailed description of the beds; but some further remarks may be added.

The most important fault (or system of faulting) in the London Basin is that along the valley of the Thames below London, with a downthrow on the north, sometimes to an extent of about 100 feet, and perhaps more, which may indeed have had some effect in determining the course of part of that valley. It was seen in section in two railway-cuttings south of Deptford (see pp. 144, 155), is proved by well-sections at Greenwich, and is lost sight of (? under the river) at Woolwich.

Beyond this it may continue further eastward, or may be joined (at a very obtuse angle) by another fault, of like downthrow, as the line of faulting seems to bend to the south at Woolwich. From Plumstead this fault runs eastward, is again lost under the river near Erith, and then apparently merges into the slight roll that affects the junction of the Tertiary beds and the Chalk on the northern side of the Thames near Purfleet and Stifford. In thus attempting to trace this fault for so long a distance one must be understood to speak with a little doubt, as there are two breaks in the chain, and as on the north of the river the beds are so much hidden by alluvium and gravel. In MR. MYLNE'S Geological Maps of London no such line of fault is shown, but that at Greenwich is made quite distinct from that at Abbey Wood. I was unable however to trace most of the lines of fault on MR. MYLNE'S map, or on the earlier one of the REV. H. DELA CONDAMINE (referred to on p. 90), and it seemed to me much safer to connect the separate exposures of Greenwich and Abbey Wood, in a gentle curved line (see also pp. 232, 233), though it is possible that two faults may join at an angle, northward of Woolwich, as aforesaid.

A small fault joins this large one at Counter Hill south of Deptford, where it was laid open in a railway-cutting (see p. 155).

There may be other faults in this disturbed tract (south-east of London); but, acting on the safe principle in geological mapping not to draw a fault unless it is actually seen, or inferred as best explaining the position of the beds, none have been marked on the map.

The probable faults at Lane End have been fully described at pp. 184, 185, and the fault seen in section at Bennet's End by Fig. 36, p. 209.

## FEATURES OF THE GROUND.

### *General Remarks.*

The various formations having been described in detail, and the disturbances to which they have been subjected having been noticed, we are in a position to consider the relation of each to the form and nature of the ground.

Before going on to the account of the features of each formation at the surface, it is well to remark that the surface is *directly* owing to denudation, a great thickness of overlying beds having

been removed: *indirectly* of course the various disturbances, slight though most of them may be, have had an effect on the form of the ground; but simply by leading the denuding agents in certain lines, and not by actually forming the features of hill or valley.

Thus where we find a fault or fold running along a ridge or valley we have no right to say that the ridge or valley has been formed by the fault or fold, but only that its formation may have been in the first case determined by the fault or fold, giving rise to a line of weakness or of strength, which would more readily yield to, or would more strongly withstand, the denuding forces that have afterwards acted on the rocks. For instance the Valley of the Thames just below London has not been formed by the fault that runs along it (see p. 485), although its course may have been partly determined by that fault and other neighbouring disturbances, for over that area beds have been removed to an extent of at least 500 feet (the London Clay and the Bagshot Beds), so that the vertical loss by denudation is five times as much as the downthrow of the fault, and very likely much more, as higher formations may have once spread over there.

In like manner the flat arch of the Isle of Thanet (far eastward of our district) is not simply owing to the Chalk having been thrown into that form, as at least 600 feet of other formations (the London Clay and the Lower London Tertiaries) have been denuded, off that tract. The above are really trifling thicknesses of removed rocks. To understand the vast masses that have been carried off in other parts of the kingdom, the reader is referred to SIR A. RAMSAY's sections of Wales.\*

Sometimes moreover the stratigraphical arrangement of the beds is exactly the reverse of the contour of the surface: a geographical hill is often in a geological trough, and a geological arch in a geographical valley. Nor need we be surprised at this, for even here the stratigraphical arrangement has determined the surface-contour: where the beds have been thrown into the form of a trough or basin, be it ever so gently, there they oppose greater resistance to denudation, from their inward dip; but where on the other hand they have been elevated, ever so slightly, into an arch or dome, there they yield the more to denudation, from their outward dip and from their tendency to fissure.

Formations that are of uniform structure throughout, comparatively thick, and wide-spreading, generally give rise to a more or less undulating country, whilst thinner and more varied formations tend to cause a more broken outline. Gravelly deposits, whether at a high or at a low level, mostly form flats, although the gravel may be thin. Sharp slopes are formed either by comparatively strong rocks, like Chalk, that can fairly resist wearing actions and can keep a high angle of slope without falling; or by loose rocks that readily disintegrate and fall, so that their slopes are often at nearly their greatest possible angle, where the fallen matter is constantly carried off; in the latter

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\* Vols. i. and iii. of the *Geological Survey Memoirs*.

case however the slopes are comparatively short. Clays, which are tenacious but prone to slip, cannot support a high angle of slope, but give way, as may be well seen in railway-cuttings through the London Clay, so as to form slopes of irregular surface.

Our district is of course without those bold features that occur in harder beds; but the softer rocks that we have to deal with have beauties of their own, though of a less picturesque kind, which no true lover of nature will despise. In the Chalk-escarpments of which but a short length occurs in our district we have perhaps the most perfect specimens of graceful contour in the kingdom, whilst the lower and less-marked Tertiary hills often give rich wooded masses on which the eye delights to rest. Though the slopes are mostly very gentle and the hills of no great height, yet from the absence of any very high neighbouring ground, to dwarf that with which we have to deal, there is often something akin to grandeur, and the breadth of country to be seen from many of the higher spots is remarkable, not only from its extent, but from the way in which its great tracts of cultivated land, its fine parks and its clustered buildings, speak of wealth and of civilization.

#### *Gault and Upper Greensand.*

The Gault forms, after the general manner of clays, a slightly undulating plain, in the north-western corner of the district. Above it the firmer beds of the Upper Greensand cause a low ridge, facing north-west, with a dip-slope in the opposite direction; but these features are so dominated by the great Chalk hills as to be barely noticeable.

#### *Chalk.*

The Chalk forms a markedly undulating country, with ranges of rounded hills and with deep branching valleys, crossed at intervals by larger valleys with streams, flowing, for the most part, in the direction of the dip.

When bare of surface-deposits the Chalk-tract is remarkable for its fine open downs, carpeted with short soft turf, and sometimes with scattered bushes of juniper or of box.

When however, as is more usually the case, the higher parts of the undulating Chalk-tract are covered by a surface-deposit of clay or of brick-earth, instead of the broad turf-clad downs we find either ploughed fields or thick woodland, the chief tree being the beech, which thrives best on a clayey soil over chalk, and indeed is almost the staple crop of the country near High Wycombe, where it is largely grown for chair-making. The sameness of the wide and more or less clay-covered Chalk-tract is often broken by the outliers of the Tertiary beds scattered over it, which mostly form small hills rising above the level of the neighbouring Chalk, and sometimes are large and high enough to be marked objects a long

way off. The larger outliers indeed, when seen by the practised eye, can at once be distinguished as masses of the Tertiary beds, from a distance of many miles.

The chief feature of the Chalk however is its escarpment, or the great ridge along which the formation is cut off. Only a small part of this, from above Bledlow to above Wendover, comes within our district.

It may be well to explain the sense in which the word "escarpment" is used in this memoir, as it is sometimes used in a loose way by geologists, for any line of hill that is scarped or cut out (as indeed all hills are), in which sense it is really useless, meaning simply a hill-range, whereas if made a technical word and used in the limited sense, in which it is mostly understood, it is very useful. It may be defined as "the bounding ridge" of a formation or bed, that is to say the ridge along which a formation or bed is cut off, and beyond which it does not extend, except in the form of outliers; it follows the line of strike. The North Downs and the Chiltern Range are Chalk-escarpments; the sharp hills along the Valley of the Thames near Marlow and Maidenhead are not.

MR. JUKES-BROWNE contributes the following note:—"The White Cross hill, west of Risborough, is remarkable for the two small conical hills at its northern and southern promontories. To an observer standing on either of the terminal hills it does not seem difficult to understand the method of their formation. Both slopes of the promontories are indented by depressions which have been formed by the detritive action of rain, and which lead down into the combs on either side. Two of these depressions have in each case been so widened and extended by the rain directed into them that they have met on the summit of the ridge, and have formed a col or depression across it, so as to cut off the terminal portion of the promontory."

"The northern hill is still capped by a platform of Chalk Rock and is united to the main mass by a neck of that bed. The other is entirely separated and only a few fragments remain of its former rock-cap; still it is easy to carry back the mind to the time when it too was united across the col by a continuous platform of the hard rock, and to imagine the gradual disintegration, erosion and removal of the jointed rock at the heads of the two depressions till the hill was isolated, but still capped by an outlier of the rock. Subsequent detrition would gradually reduce the area of the summit and produce the conical form, but this form was as certainly due to the original capping of rock as earth-pillars are due to the protective boulders which cap them."

"Another such conical hill stands in front of the Long Down outlier south of Kimble, and is shown on the right side of Fig. 104."

That part of Chequer's Park which includes the hills above the Kimbles, with its combs, its "Velvet Lawn," and its masses of wood is very beautiful. The dark bushes of box, with the higher and nobler masses of beech, and, in onecombe, of the tapering

larch, and here and there bosses of white-flowered elder on the soilless slope of chalk, are not to be surpassed. The even grassy walk along the bottom of the long deep-cut combes well sets off their sharply-sloping sides.

MR. JUKES-BROWNE says of this that "the escarpment is very steep and is trenched by some magnificent combes, several of which remain in their natural state, the slopes being partly covered with short green turf, partly with thickets of box, and partly with copses of trees, the whole forming a piece of scenery unsurpassed by that of any other place along the escarpment."

Fig. 104 is a sketch of the head of the combe facing Great Kimble church. It shows how conical mounds of chalk may be left by the wearing away of that rock by rain and springs. The combe forks at the base of the hill in the foreground (where the Totternhoe Stone crops out) and the two branches have already cut back their channels in such a way as to meet again. In time the gradual dissolving away of the chalk along these channels may make the hill still more detached, like the one further off on the right. The signs of subaërial denudation are plentiful along the great Chalk hills here and to the east.

#### *Lower London Tertiaries.*

From the thinness of the three divisions of this set of beds they do not of course make so marked a feature as that of the Chalk; but where they form broad tracts they have great effect on the scenery, which from the varying nature of the beds is of a varying kind. As the middle division alone ranges throughout our district, the upper and lower divisions being confined to its south-eastern part, the three will be treated of together.

Towards the eastern part of Surrey these lowermost Tertiary beds begin to have a well-marked escarpment, rising from above the Chalk, as on the east of Ewell. At Beddington and Croydon, where the Thanet Sand has thickened, this is also the case.

Along the outcrop of these beds in Surrey, especially towards the east, there are many villages, the line of which indeed is in itself enough to roughly mark the junction with the Chalk. Their position is doubtless owing to the springs that occur along this line.

Beyond Croydon, eastward to the valley of the Cray and northward to that of the Thames, is the broadest tract of the Lower London Tertiaries, and there occur the most marked features of this set of beds, owing chiefly perhaps to the development of the pebble-beds of the Blackheath Series, the Woolwich and Reading Beds being often thin, but the Thanet Sand greatly helping to form the gentle hills.

On the south of this tract the escarpment forms the well-known range of the Addington Hills, Hayes Common and Holwood, the high grounds of which consist of the pebbly and sandy Blackheath Beds, with a more or less even top, furrowed by little valleys, covered with wide spreads of heath, of gorse and of broom, or



Figure 104. "*The Head of the Combe.*"  
*From above and just east of Warren House, Great Kimble.*



Just beyond the bushes, on the right front, there is a sharp hidden slope, down to a deep hollow, not a flat, as made by the wood-cutter.

with plantations of firs, and giving rise to some of the most beautiful scenery near London.

Northward from the escarpment the ground slopes to a lower level, the slope being slightly broken here and there by an outlier of London Clay, and being affected by slight rolls (see p. 482) which bring up the beds along certain lines; thus when seen from Chelsfield (on the east) the slope northward is at an angle of  $2^{\circ}$  or  $3^{\circ}$ , but before getting to Chiselhurst there is a rise in the same direction. The main mass of the Thanet Sand only just crosses the valley of the Cray, the other divisions being scarped by that valley and by the Thames, from Erith to London, along which latter course the form of the hill-range does not seem to be in the least changed from being near a line of fault, as there is nothing in the form of the ground, that would lead one to infer the presence of a fault.

The Blackheath pebble-beds assert the flat-forming tendency of a gravel-deposit very markedly from Bexley Heath to Blackheath, and often produce short sharp slopes where cut into by valleys. To this division is chiefly owing the beauty of the country around Chiselhurst, which is partly due however to the elevation that has brought up lower beds to the surface, and given greater variety to the scenery.

In South Essex the Lower London Tertiaries have no great feature, and are much covered by gravel, nor are they strongly marked in their main mass between the Thames and the Medway, except in the great spur of Shorne (just to the south of our district), which spreads over high ground and is almost an outlier.

On the west and north we have to deal with the Reading Beds only, of which there is little to be said. They mostly form the lower part of a long slope that chiefly consists of the overlying London Clay; often too the Chalk runs a long way up the slope.

From their varied character the Reading Beds sometimes give rise to the usual features of a sand-country (on a small scale), but at some places they are nearly all clay. The frequent occurrence of swallow-holes at their junction with the Chalk has been already noticed (p. 125). From Twyford to Bray the outcrop is along the lowest ground, the Chalk rising up higher on the north and the London Clay on the south, but northward they spread to a high level, overlooking the valley of the Loudwater, though, from the wide covering of gravel, their outcrop is much hidden, and their effect on the surface much lessened.

The larger outliers of the Lower Tertiaries mostly form hills rising gently above the neighbouring Chalk. Of course where a large mass of London Clay occurs on them still greater prominence may be given: the large outlier near Wargrave, with its two hills of London Clay, can for instance be clearly made out from the high ground of Richmond, a distance of more than 22 miles in a straight line.

*London Clay.*

The thick mass of the London Clay mostly has a well-marked escarpment, sometimes reaching to a height of more than 400 feet above the level of the sea, in a long and gentle slope, forming a wooded range of hill that can be seen a long way off.

Where it covers a large extent of surface this formation by no means gives rise to a perfect flat, a shape of the ground which indeed seems to be mostly confined to gravelly deposits; but it forms a very gently undulating tract, chiefly of grass-land. The highest hills are capped with gravel or Bagshot Sand.

The northerly slope of the tops of the London Clay hills of Norwood, Sydenham, and Forest Hill is about  $1^{\circ}$ , when seen from Chelsfield, many miles to the east, and this would be much the same as the angle of the dip; their scarped face is of course at a much higher angle, sometimes perhaps nearly  $10^{\circ}$ , which is the angle of the southern slope of the equally conspicuous mass of Shooter's Hill, the rise of which, from above the plateau of the Blackheath Beds is so well-marked. The impermeable clay, yielding to erosive actions, has been cut back, whilst the permeable pebble-beds have allowed the rain to sink down into the ground, instead of leaving it to exert its wearing power on the surface.

Whilst on the south the escarpment often rises almost at once from above the underlying beds, as in the cases just mentioned; on the north the main ridge is generally some way back from the outcrop of the Reading Beds, the shape of the ground being as roughly shown in fig. 105.

*Bagshot Beds.*

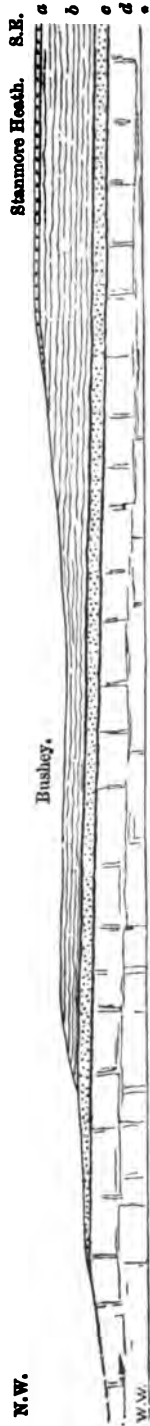
Of these we deal only with outliers, and therefore have little to say. The sand-masses of Middlesex form the tops of the marked hills of Harrow, Hampstead and Highgate; whilst in Essex the pebble-beds, with the underlying sand, again form the uppermost part of the most conspicuous hills. Of this latter county MR. H. B. WOODWARD says that "the Bagshot Beds are generally characterized by Commons, Greens and much woodland."

*Drift, &c.*

Many of the surface-deposits have a marked influence on the form or character of the ground. The Brick-earth and the Clay-with-flints, over the north-westerly Chalk-tract, have perhaps some effect toward giving a flatter shape to the higher ground, and they have a powerful effect on its character, forming, instead of open chalk-downs, a clayey district, which supports large masses of woods and is of an agricultural instead of a pastoral kind.

The Boulder Clay gives the usual appearance of a clay-country; but, as it occurs chiefly over the London Clay, it does not, as a

Figure 105. Section from a Point about a quarter of a mile S.W. of Bushey Grove to Stanmore Heath.



Horizontal scale, 3 inches to a mile. Vertical scale, twice as large (880 feet to an inch).

\* \* Sea-level (approximate).    a Pebble Gravel.    b London Clay.    c Reading Beds.    d Chalk.

The coming on of the London Clay over the Reading Beds has been made too abrupt, and the ground at and to the left of Bushey has been drawn rather too high, so that the slope on the right is hardly exaggerated.

rule, cause much change in the surface-features, except where it rests on Chalk or on Bagshot Beds.

The various gravels of the higher grounds give rise to nearly flat plateaux, which are sometimes of wide extent, though much cut through by the erosion of valleys.

The gravels and brick-earths of the valleys form plains, spreading upward, with a gentle rise, from the river or its marsh, and, where in force, being also sometimes marked by more sudden rises, by which long and broad terraces, gradually rising in height, are formed, instead of one continuous plain, as has been already described in detail.

Whilst these gravel-flats are dry, except where the gravel is very thin, low, and water-logged, the flats formed by the Alluvium are damp and marshy, being often subject to floods, and being indeed only protected therefrom artificially.

Although therefore the surface-deposits are often so thin that it is difficult to show them distinctly, without exaggeration, on the Geological Survey Sections, which are on the scale of six inches to a mile, yet they often have a very great effect in changing the surface of the country, from the aspect it would have, in their absence, to one of a very different character. Thus what would otherwise have been a gently undulating clay-tract, with beds at the surface which are impervious to water, may be planed down to a flat, covered by gravel, which, though perhaps rarely 20 feet thick, forms a plain that is dry at the surface, on account of its great permeability by water.

## DENUATION.

### *General Remarks.*

That the present contours are owing directly to denudation has been remarked already, and more particular attention may now be drawn to the important work thus done.

Evidence of the former extension of beds over areas now bare of them is given by the way in which bed after bed is cut off on hill-sides, and more markedly by the occurrence of outliers far beyond the present boundary of the mass of various formations.

Denuding agents have not only formed the present surface, but have had their effect in the past on the relations of the different formations, where one lies irregularly on that below. The materials of our Tertiary beds must have been derived from some earlier land. The pebbles of the Blackheath Beds indeed may be inferred to have come from the Chalk that once spread over the Weald, the planing down of which area would seem therefore to have begun at an early Tertiary age.

In the London Basin however there are few unconformities, to tell us of the erosion of one formation before another was laid down on it: in the case of the westerly thinning of the London Clay (mostly beyond our district) there are no means of saying how much has been caused by denudation and how much by original

irregularity of deposition. The only marked case of undoubted erosion of older beds is given by the Oldhaven Series, which in places distinctly cuts through the Woolwich Beds, sometimes through the Thanet Beds also, and even cuts off part of the Chalk, just south of our border.

The establishment of palæontological zones in the Chalk has led to the conclusion that the uppermost division of the Upper Chalk is not present in our district, whether in the Chalk tract, or beneath the Tertiary beds; but, so gradual in its effect is any erosion of the Chalk that has taken place before the deposition of the Tertiary beds, that our junction-sections, some of which are of great length, show no discordance between the two groups. MR. JUKES-BROWNE has come to the conclusion that, in the western part of our district, there is an unconformity between the Chalk and the Reading Beds; but though this is shown by an ideal section, across some miles of country (see fig. 4, p. 78), yet the actual junction-sections of the neighbourhood would not lead one to infer any unconformity. It should be noted however that there the lowest member of the Tertiary Series, the Thanet Beds, is absent.

The most marked of the erosions that have taken place in the district, before the final, and still existing one, is that which came between our highest Eocene beds and the Drift (classing therewith all the various gravels and brick-earths); for we see that the various members of the Drift rest irregularly on the older formations, from the Chalk upwards. Speaking of southern Essex, where the greater part of the Glacial Drift of our district occurs, MR. H. B. WOODWARD writes that "the main features were probably marked out before any Glacial deposits were accumulated over this tract, for the Bagshot Beds had then evidently been separated into outliers over the areas where they are now represented. Upon the irregular surface that had been produced, by various agents of denudation, the Drifts were deposited, the Glacial gravels having probably a partial distribution, though they seem to have suffered erosion before or during the deposition of the Boulder Clay. This last must have covered very nearly the whole of the tract in question, and has suffered much from denudation in later times; indeed, together with the Glacial gravel and the Bagshot pebble-beds it was subject to much erosion, and this gave rise to those irregular and variable gravels that lie indifferently on Glacial and on older beds (see Chap. 18). During this stage, and in some degree influenced by then existing valleys or hollows, the drainage would mark out the courses taken by the present rivers. Considerable erosion has taken place since, by subaërial agencies, in deepening these valleys and in forming other minor valleys. Generally the streams have cut through the Drift to the London Clay, and, whilst it may be said that the main features of the country are Pre-Glacial, the minor features are Post-Glacial, or later than the Boulder Clay."

Something must be said of the way in which the denudation that has modelled our present surface has been carried on; but

this is perhaps not the place to enter into a theoretical and controversial question; so I shall content myself with giving the view now generally held. Geologists now mostly agree that our hills and hollows, our escarpments and valleys have been fashioned by "meteoric" or "subaërial" and not by marine action; that, whilst the sea has at various times planed down the surface, rain, rivers, &c. have, after the elevation of a plain so formed, furrowed its surface and caused irregularities; that in fact actions now going on, apparently small in themselves, but powerful from long continuance, have produced effects that at first sight may seem beyond their power. It is, I believe, almost universally acknowledged that water in some form has been the agent in forming the varied features of our scenery, and those who hold that it has not been in the form of the sea do so chiefly on the ground that the sea has left no mark of its action, and does not produce such results now-a-days, and that the agencies we now see working are enough, given a fair amount of time, for the task, especially as they may have been at times more intense than now.

The great amount of matter carried off the land by surface-waters every year, whether in the mechanical way, as when sand or clay are acted on, or by solution, as is so much the case with Chalk, is hardly appreciated; but it has been estimated that the loss by these means over our island is much greater than the waste of land along our coast, although, from the ease with which the latter may be seen, great changes taking place within the memory of man, the reverse may commonly be supposed to be the case. It should be remembered that whilst the action of the sea is confined to one narrow border of land, meteoric actions (of rain, rivers, frost, &c.) are everywhere going on, and therefore have a far larger base of operations, even in an island with a comparatively large coast-line.

### *Valleys.*

That valleys have been gradually scooped out by the action of the streams running in them is now generally allowed by English geologists, but the origin of escarpments is not so generally believed to be owing to meteoric actions, though the formation of these two classes of features are really of the same kind. River-valleys, often run for some way along escarpments, the escarpment forming one side of the valley; but on the other hand, valleys also often cut through escarpments.

The chief valley of the London Basin, that of the Thames, enters our district on the west, at Shiplake, where it receives the Loddon and then turns northward (taking the direction indeed of its tributary) through the Chalk to Remenham, with a sharp slope on its right bank and a gentle one on its left. It then again turns eastward to Cookham, with gentle and sharp slopes on either side, and then southward to Bray, with a gentle slope on its right bank, and a very sharp one on the left, from Hedsor to Taplow.

At first sight one would have expected the river to have continued its easterly course from Sunning (in Sheet 13), and to have worn a channel along the softer Tertiary beds of the lower ground between Twyford and Bray, instead of going out of its way to make a deep winding valley through the less yielding Chalk. It seems likely however that the present course may have been determined before the present shape of the ground was established, and that when the river turned northward from Twyford the lower ground east of that place did not exist; but that the Tertiary beds then spread in mass over the quadrangular Chalk-tract (bounded on three sides by the river) between Henley and Maidenhead, the outliers now scattered over which are signs of that extension, these beds having in great part been worn off the tract in question since the course of the river was marked out.

In its course through the Chalk the valley of the Thames is comparatively narrow, and the sharply-sloping parts, or river-cliffs, are mostly covered with noble woods of beech from top to bottom, but are sometimes bare. In its course through the Tertiary district now to be described, the valley is, on the other hand, broad and with gently sloping sides, though near Egham and Richmond, where the river flows near to the bounding hills, these are fairly sharp. This difference in the form of the ground is clearly owing to the different nature of the formations cut through.

At Bray the river turns eastward again, but the thick deposit of gravel along the low ground hides the underlying beds, and it is only from borings lately made that we know that Tertiary beds are here beneath the river, though the ground on either side consists of these beds.

At Windsor it turns south-eastward, round the fine chalk-cliff on which the Castle stands, and then the valley broadens out, both from the southerly trend of the river and from the broad low tract of old river-gravel and brick-earth on its northern side. The right bank is formed by the Bagshot hills from Egham to Esher, and then by London Clay; but the valley narrows further east, though to nothing like what it is in the Chalk, on account of the northerly flow of the river from Kingston to Richmond. In this course it will be seen that whilst the northern bank runs in a fairly direct line, the windings of the southern bank cause the changes in width of the valley. Below Richmond the Thames has a pretty constant easterly course.

Below London the valley again cuts into lower beds, at first on the right side only, where it seems to run for some miles along the line of a fault (see p. 485), and we have on that side a comparatively sharp slope of the Tertiary beds, and on the left bank a gentle rise of old river-gravel and brick-earth.

It is clear that from a little above Windsor to some miles below London the general tendency of the Thames has been to cut its channel further and further southward; as it is on the north that



we find the widest tracts of the old river-gravels, and on the south that the river comes nearest to the hills.

Below Erith the river again enters the Chalk, but without making such marked features as in the higher part of its course, though the valley becomes narrower than in the Tertiary district above, and though sometimes the banks are steep, as indeed is implied by the name of the village of Cliffe. The lowest part of the valley is again in London Clay, with at first a sharp slope, and at last an absolute cliff on the north, at Southend.

The probable former extension of this valley, by Shoeburyness, Foulness, etc. has been noticed on p. 474.

With regard to the loss of land along the cliffs between Leigh and Southend, the chief part of our district where tidal water washes the base of a cliff, one may quote from a recent paper:—"At the Hamlet farm in Prittlewell, which has about 500 yards on the shore,  $2\frac{1}{2}$  yards are annually washed away, calculated from the last 60 years. The cliff is 21 feet high, and this is but a specimen of what is happening eastward in neighbouring lands."\*

The left side of the valley of the Cray from above Orpington is the escarpment of the Woolwich and the Oldhaven Beds, and almost of the Thanet Sand too, this last only just crossing the river between North Cray and Crayford.

North of the valley of the Thames there are other valleys, formed by streams, which, rising from the Chalk, flow south-eastward, in the direction of the dip, that is in the line of greatest fall of the beds, or in other words, the natural direction of drainage. These valleys therefore are for the most part parallel. They partly cut through the great escarpment, (mostly north of our district) but not wholly; and there is little doubt that they have been caused by the slow wearing and dissolving action of the streams. That of the Chess does not run back to the escarpment.

Of this tract MR. JUKES-BROWNE, who has lately spent much time therein, sends the following notes:—"The small part of the Chalk-escarpment in our district is not an unbroken range, like that to the south-west, from Bledlow to the Thames. The scarp of the Lower Chalk is indeed continuous, but the upper part of the escarpment, or that which lies above the outcrop of the Melbourn Rock, is separated into blocks by broad gaps or passes which open southward into the valleys of the Loudwater and of the Misbourn. These gaps seem to be truncated parts of valleys which date from a time before the escarpment had been cut back to its present position, and when its front formed a continuous ridge some miles in advance of its present line: the valley gravels which lie within them and which have clearly had a more prolonged extension (see p. 447) confirm a supposition which is suggested by their general conformation."

"The two passes which isolate the Upper Chalk outlier south of Kimble are particularly picturesque, the upper slopes being densely wooded on either side; the more southerly of the two

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\* F. C. J. SPURRELL, *Archæological Journal*, 1885.

being narrower, has somewhat bolder features and a more trough-like form; the other is wider, with a flatter bottom, and its northern end is occupied by the demesne of Chequers Park, the small outlier of Beacon Hill, above Ellesborough, being all that now remains of a ridge that once separated this space into two parts. It would thus appear that there were originally three tributary valleys here, all opening into Hampden Bottom, that their ends have been breached by the recession of the escarpment and widened into the spaces which now exist."

Whilst the Loudwater, Misbourn, and Bulbourne rise from the Chalk near its escarpment, and flow in a fairly direct line into the Thames, the water thrown out from the Chalk and Upper Greensand to the north of their rising-points (near Prince's Risborough, Wendover, and Tring) flows down the lower part of the Chalk escarpment, or down that of the Upper Greensand, and over the Gault plain into the Thame, which joins the Isis near Dorchester, the two rivers then forming the Thames (Tamesis; Thame-Isis); and therefore this latter water, though at first flowing in a direction almost opposite to that of the Chalk-valleys, at last comes to the same spot, but by a very much longer route.

The change in the course of the Loudwater at Woburn, where it comes into the Tertiary district, is noteworthy; it turns at a right angle and flows into the Thames; whereas one might have thought that it would have kept on its south-easterly course along the Hedgerley and Fulmer Valley. The Misbourn however holds its course through the Tertiary beds, though but for a short way, until it joins the Colne. This last river, which receives all the above-mentioned Chalk-streams but the Loudwater, flows roughly parallel to the Tertiary escarpment from the west of Hatfield Park to the south-west of Rickmansworth; its course seeming to be determined simply by that ridge.

The joint escarpment of the London Clay and of the Reading Beds, eastward of Hatfield, forms the right bank of the valley of the Lea, until, after changing to a southerly course (just beyond our district) that river enters the Tertiary tract below Hoddesdon, whence, continuing its southerly course through the London Clay, the valley has a gentle gravel-slope on the right and a fine range of clay-hills on the left, until it joins the valley of the Thames.

## CHAPTER 28. ECONOMIC GEOLOGY.

## MATERIALS USED IN BUILDING.

*Stone.*

IN old times chalk was used for building much more than it is now, as may be seen from the quantity of it in churches, for instance St. Alban's Abbey, which seems to be built of chalk or of Totternhoe Stone, together with Roman bricks. It is really well fitted, from its lightness, for inside work, especially for vaulting; but in outside work it is generally found to have suffered much. In Bedfordshire and in Hertfordshire the Totternhoe Stone, which is darker, more gritty, and harder than the mass of the chalk, must once have been the chief building-stone of the country where it occurs.

The flints from the Upper Chalk have also been used in all times for building, and they form perhaps the most lasting material in the kingdom. They may be seen, in the rough state, in Roman work, as near St. Alban's, and in many old churches of various dates; but they are also used, with better effect, after having been dressed to a flat rectangular face, of which there is a good example in the exquisite little Decorated church of Shottesbrooke in Berkshire.

The blocks of greywether-sandstone, that are either found on the surface, or are quarried from the high-level brick-earth near Wycombe (see p. 288) form an admirable building-stone, dressing easily to an even face, and being almost indestructible by the weather, for the dressed surfaces harden by exposure. They are also of a pleasing grey tint. Examples may be seen at Windsor Castle, great part of which is built of this stone. Small cuboidal dressed blocks of greywether-sandstone are also used for paving; indeed MR. JUKES-BROWNE tells me that the stones got from the brickearth are now more used for this purpose than for building, in Risborough, &c.

For the formation of concrete, which is really an artificial stone, various gravels are used, notably the River Gravels, where docks are largely made in them.

*Brick-making, &c.*

In brickmaking chalk is often used, being ground up and mixed with the other materials in a liquid state. This is chiefly below London, where the valley brick-earths are worked, at Ilford, at Erith, and at Crayford.

The mottled clays of the Reading Beds are often of much value. Near London the well-known fire-bricks of Nonesuch Park (Ewell) are made from this formation. This clay is worked for the manufacture of tiles, of draining-pipes, and of coarse pottery,

for which it is well fitted, from its ductility. The sand is used for mixing with the clays in brickmaking, &c.

The laminated sand and clay that either forms the top part of the Woolwich Beds, or that locally represents the Blackheath Beds, near Lewisham and Bromley, forms a good brick-earth, or is useful for mixing with other earth; but its occurrence to a workable extent seems to be limited.

The stiff London Clay is used for making tiles, pipes, and sometimes coarse pottery; and also, when mixed with sand, &c., for bricks. The loamy basement-bed (when thick) or the equally loamy topmost beds (that pass up into the Bagshot Sand) form of themselves a good brick-earth.

The Boulder Clay is sometimes worked for brick-making, but it needs washing, in order to get rid of the stones.

Probably the largest source of bricks in our district is from the various loams, or brick-earths, of the Drift, which vary in composition from sandy clay to clayey sand. Some of these being stony, or containing calcareous concretions, have also to be washed, and in some cases the resultant mixture is allowed to flow by gravitation, being in a semi-liquid state, from the pit where the earth is worked to the yard where the bricks are made.

The marsh-clay of the alluvial flats is rarely worked. At Bridgemarsh, an alluvial island in the tidal Crouch, and in the parish of Latchingdon, brick- and tile-works were established, and the earth is said to consist of  $2\frac{1}{2}$  feet of red clay (= the brown discoloured top) and from 14 to 30 feet of mild clay.

A sand which is dredged up from the shoals in the lower part of the Thames, and which may be the same as the bed sometimes found at the base of the alluvium, is largely used for dusting the inside of the moulds used in brick-making by hand. For this purpose the sand is taken far and wide from where it is got.

#### *Lime, Cement, Whitening.*

The chief economical use of Chalk is in the manufacture of lime, kilns for that purpose being very common, and in some places large quarries have been worked chiefly for this. The Chalk indeed is the only source of lime in the district.

This rock is also one of the ingredients of Portland Cement, being ground up and mixed with clay, from the Gault and from alluvial deposits. There are large works on the Thames below London.

The septaria (hard clayey calcareous concretionary masses) found in the London Clay were used in the manufacture of the so-called Roman Cement; but this manufacture has been for some time extinct, Portland Cement being both better and cheaper.

One manufacture is greatly dependent on chalk for its raw material, that of "whiting" or "whitening," which is sometimes made on the spot where the chalk is quarried, but sometimes in

other places, for instance in London. Practically it is simply levigated chalk, from which the coarser parts have been separated by washing.

#### APPLICATIONS TO THE LAND OR TO MANUFACTURES.

##### *Manure.*

Chalk is used as a dressing on clayey lands, sometimes on sandy Tertiary beds and with equally good effect on gravelly land. In the tracts where there is much of the superficial deposit of "clay-with-flints," this application to the land used to be very general, and though sometimes the chalk was brought from a pit, the usual method was to sink shafts in the field and work the chalk in short galleries therefrom. I have been told, in Berkshire, (beyond our district), that one dressing serves for about 20 years. When applied to the London Clay it is often in the form of lime. A full account of the method in which the chalk is got from underground, for application to the land, has been given by MR. F. J. BENNETT.\*

In one case only have I seen the estuarine shelly clays of the Woolwich Beds used as a top-dressing for land; by MR. COLES CHILD, at Bromley in 1871.

The Boulder Clay has been largely dug for marling fields, especially those of the London Clay. Its use however is generally going out, though the large amount of chalk in it cannot fail to be of service. The following note, by MR. WOODWARD, seems to show the fertility of a Boulder Clay soil. "The best wheat-land is on the Boulder Clay, and in a field at Writtle, near Chelmsford, wheat was grown on it for six successive years."

##### *Road-metal.*

The chalk-rock is much worked for use on roads, and thereby many fresh sections have been laid open of late years.

The flints of the chalk form a good material for roads, when they have been well hardened by exposure; but those taken fresh from the chalk are brittle. In many parts they are picked from the fields, on the brick-earth and clay-with-flints over the high Chalk-tract, where they are over plentiful.

MR. JUKES-BROWNE notes that "a mixture of Chalk Rock and flints is said to make a better surface than either used alone."

The pebble-beds of the Blackheath Series are an indifferent gravel, from their want of binding power, but they are largely worked in the absence of better gravel, and have been much used for ballast on the London Chatham and Dover Railway.

All the Drift gravels are of course used in the making and mending of roads, the finer parts being sifted out for paths. The flints in these have mostly become hardened.

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\* *Essex Naturalist*, no. 12, pp. 260-265. (1887.)

*Foundry-sand, etc.*

Except for work connected with building, the tract described in this Memoir yields few materials that are applied to manufacturing purposes.

Besides yielding a fine sand in the district south-east of London, the Thanet Sand is noted from its more clayey bottom part being a good foundry-sand, for which it has been worked at Charlton; indeed it is said to have been the occurrence of this moulding-sand hereabouts that determined the site of Woolwich Arsenal.

Flints are used in the manufacture of glass and porcelain. Probably some of the Tertiary sands have been used for glass-works; but it is doubtful whether any are now used, from our district.

## WATER

It is well known that the greater part of the water that supplies London comes from the River Thames, and with a surface-supply of this ungeologic nature we have nothing to do here. It has a most extensive literature; but luckily one can refer the reader to a single thorough account, originally prepared, by the late SIR FRANCIS BOLTON, for the International Health Exhibition of 1884.\* This work refers however to London only and only to public supplies: in the following pages, and in the somewhat voluminous records of Well-sections (in Vol. ii.), some reference will be found to other districts and to private works.

*Springs.*

As springs are merely the overflow of underground water they claim a passing notice here; though, as geologists, we are interested chiefly in attempts at water-supply by sinking or boring wells.

The springs from the lowest part of the Chalk, along the escarpment, have been noticed on pp. 61-63.

Along the various chalk-streams there are many springs, and in many cases those from which the streams start vary in position. After wet seasons, the Chalk having become more fully charged with water, the outflow takes place higher up the valley than is the case at other times, and what is usually a dry valley becomes possessed of a running stream. These are the bournes or nail-bournes of our district, the winterbournes, levants and gypsies of other chalk-tracts, and are caused simply by the rise of the underground water-level above the level of the lowest ground, which must of course result in outflow.

Of the chalk-springs the following is an example:—"In the beautiful grounds of "Otterspool" are several . . . springs, giving forth never-failing streams of the clearest water. Six are at the bottom of the pool, and, together, yield no less than 300,000 gallons of water a day, forming a not inconsiderable

\* London Water Supply. Pp. viii., 245; 9 maps; 9 folding tables. 8°. London, 1884. New Edition, by MR. P. A. SCRATCHLEY, 1888.

affluent to the Colne."\* The yield mentioned however is not large. The pool is 16 feet deep. Another note adds that the springs "are said at times some years ago to have yielded a million [gallons] . . . the water is so clear that the springs themselves, and the sides of the fissure in the chalk which forms the pool, can be distinctly seen."†

The following account of two springs near Leatherhead is taken from a paper by MR. J. W. GROVER. There is a "small one, just above the town on the Dorking Road . . . which yielded about 500,000 gallons of water a day in 1883; and the other, on the north side of the town close to the railway, rising in a mill-pond of 7 acres, and having a fall of 11 feet 5 inches into the River Mole. This spring, in March 1883, was yielding 3,619,000 gallons . . . daily at a level of about 110 feet above Ordnance datum . . . The spring bubbles up from a deep pit in the bed of the pond."‡ The well for the Waterworks, about 500 yards to the east, has not interfered.

The above are only given as specimens, if treated in detail the chalk-springs might need many pages.

There are here and there sandy beds in the London Clay, which allow the entrance of water, and are probably the cause of the few small springs that have been found in this formation. The water from the London Clay is often medicinal, so much so in one case, that of Epsom, as to have given a name to the commonest aperient salt. One of the medicinal springs of Essex has been noticed at p. 261, and I have heard that a spring on the south of Chigwell Row was much appreciated in the neighbourhood. Other places (for instance Hampstead, Islington, Kilburn, and Norwood) were once famous for the effect of their waters, which however are now hardly known. In the case of Hampstead the water comes from the junction of the Bagshot Sand and the London Clay.

Along the Fleet valley there have been famed springs, thrown out from the gravel by the London Clay, and which have given their names to the thickly-housed districts that were the means of their destruction (Clerkenwell, Bagnigge Wells, and Coldbath Fields), whilst Holborn (Old bourne) is suggestive of the brook itself, the Fleet Ditch of years ago. In other parts of London we find such names as Walbrook and Holywell, where now neither brook nor spring exists. These springs were probably the chief reason for the settlement of man around them, and it is by the growth of the population they attracted that they have been destroyed.

#### *Shallow Wells.*

In tracts where there is a goodly spread of any of the Drift gravels, or of the Bagshot Beds, over the London Clay, the water falling on the permeable gravel and sand, sinks down, until

\* ANON. [? J. HOPKINSON]. *Proc. Geol. Assoc.*, vol. iv., no. 5, p. 284. (1875.)

† *Trans. Watford Nat. Hist. Soc.*, vol. i., pt. 3, p. xvi. (1876.)

‡ *Proc. Inst. Civ. Eng.*, vol. xc. p. 14. (1887.)

checked by the impermeable clay. In such places plentiful supplies of water may be got by shallow wells, and, so long as the tract is not thickly populated, the water may be good in quality as well as abundant. When however cess-pits are established there is risk in these supplies, and in populous parts they may lead to great evil. The placing of cemeteries on a water-bearing bed moreover is not calculated to improve the water.

Where however there is a thin protecting covering of a clayey nature, such as brick-earth or Boulder Clay, wells sunk to the gravel or sand beneath may yield good water, so long as cess-pits are not carried down into the water-bearing bed.

A note of a successful little work for getting water from the Bagshot Sand, for the supply of a house, etc. on the London Clay, at a lower level, has just been sent me (August 1888) by MR. W. GILBERT of Laindon Hill, in Essex. Near a sand-pit toward the eastern end of the Bagshot outlier there, he sunk a small well, to a depth of about 16 feet, and from this the water flows, by gravitation through pipes, to tanks near the house. It is hoped to extend this supply, which is of the more importance as to get a deep-seated supply hereabouts needs boring to a great depth.

It is from the gravel that the many shallow wells of London got their water, once thought famous for its wholesomeness and purity; indeed it was the facility of getting water in this way that of old limited the area for building. Now the water of such of these wells as remain, though it may be clear and sparkling, is more noted for the large amount of hurtful organic matter from graveyards, &c. that it holds in solution.

The common error that because a water looks clear, and has no unpleasant taste, therefore it is pure and harmless, should be noted as most mischievous: the most hurtful qualities in water are not always those that appeal either to the eye or to the taste. The shallow wells of London are now closed, at all events for domestic use; but not before they have been powerful factors in causing disease and death. An example of the kind of thing that happens with these shallow wells in crowded districts is given in the following extracts.

In noticing certain black staining in the River Drift on the site of the Courts of Justice (see p. 399), MESSRS. HUDDLESTON and PRICE remark that "in one part, below a spot which the workmen declared to have been a cesspool, there was a great blackening of the sands . . . due . . . to *Protosulphide of Iron*," and they add this suggestive note:—"The more soluble organic matters from this cesspool had passed through the porous sands during the period of its use, contributing their poisons to the waters, which percolated near the surface of the upholding clay. Clear and sparkling the liquid might appear when drawn from adjoining wells, but it doubtless proved a fatal draught to many a one who drank it. Besides these cesspools the fat churchyard of St. Clement Danes would further contribute to enrich the quality of the water in the lower wells. As an exemplification of this



we saw two coffins drawn out of the bottom of a well adjoining this churchyard on the north side—just outside the Law Courts area. They must have been there for several years. In all probability the people who inhabited the house over it, drank of this water, charged as it must have been with organic matter of the most deadly description !”\*

Where gravel at a low level comes down to a river there is of course communication between the water in the gravel and that of the stream, except where the latter may have silted up its channel to an extent enough to stop this. A good instance of such communication was given me by MESSRS. SIEMENS, as occurring at their works, in the marsh just westward of Charlton Pier. The letter accompanying an account of some borings (see Vol. ii.), which were carried through the alluvium to the gravel beneath, says :—“ we have found no water until getting very near the gravel, excepting in a few places nearest the river, where there have been small fissures or permeable layers in the ground ; on reaching the gravel however we have, in all cases, found it full of water, which evidently came freely through the gravel from the river, as we had a tide in the holes varying some 10 feet or more, simultaneously with the tide in the river.”

This kind of communication between the water of the river and the gravel has been cleverly taken advantage of, and turned to great practical account, by most of the London Water Companies that have intakes from the Thames at Hampton and at Molesey. At the latter place the gravel comes down to the river-side, but at the former there is a narrow strip of alluvium between the two, so that a communication had to be made in this case. By this means a very large supply can be taken from the river through the great natural filter of the gravel ; but the water so taken is also passed through the artificial filter-beds that form so important a feature of these works. At times when the river is in flood, and therefore far from clear, this method of taking the water is especially valuable.

#### *Deep Wells.*

The principle of getting water by deep wells is the same in whatever formation they may be made, and such wells may be roughly divided into two classes, one in which they are sunk throughout in the water-bearing formation, where it comes to the surface, and the other in which they are sunk through other formations which overlie the water-bearing one. The former class is practically of the same character as the shallow wells that have been noticed, differing only in matter of depth, and of course there is no sharp line between these two, shallow and deep being merely comparative terms. These deeper wells, made wholly through the water-bearing formation, are common enough in the tracts where the great water-bearing formations, such as the Chalk or the New Red Sandstone, are at the surface, and their depth depends on the

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\* *Proc. Geol. Assoc.*, vol. iii., no. 1, p. 54.

difference between the level of the ground and that of the plane of saturation of the rock, modified to some extent by the water-yielding power of the rock locally. From their simplicity however such wells have less interest to geologists, though often practically of great importance, perhaps indeed of the greatest.

It is to the other class of wells, those that have been sunk or bored through overlying and unprofitable beds to underlying water-bearing beds, that the geologic mind turns with satisfaction, and naturally so, for these help to satisfy the cravings of that mind for hidden knowledge. The vast amount of information that geology has got from wells, in our district alone, may be judged from the mass of details given further on in Vol. ii. of this Memoir. In addition to this geologists should remember that perhaps the grandest problem in our local geology, that of the character and range of the older rocks deep beneath the Valley of the Thames and the great city, foreshadowed as it was by the speculations of the geologist, has been practically followed out solely by the engineer, in his search for water, without which it could have remained speculation only.

These wells too have a charm even to the ungeologic mind, to which there is a sort of mystery in the rising up of water from a great depth underground, sometimes even to above the surface. Of course the explanation is simple enough: the water, the product of rain that has fallen on higher land, where the permeable beds are at the surface, has sunk downward by gravitation, between underlying and overlying impermeable beds, and, when communication with the surface is made through the last, the water naturally rises to a level more or less proportionate to, though often far below, the level of the water-bearing bed at its outcrop. It is satisfactory to find that such an explanation should have occurred to a scientific mind, and one that has had a vast influence on science, many years ago. We find DR. ERASMUS DARWIN, in giving "An Account of an artificial Spring of Water" at Derby, explaining it on the grounds that "some of the more interior strata of the earth are exposed naked on the tops of mountains; and that, in general, those strata which lie uppermost, or nearest to the summit of the mountain, are the lowest in the contiguous plains": the waters "sliding between two of the strata above described, descend till they find or make themselves an outlet, and will in consequence rise to a level with the parts of the mountain where they originated."\*

The term Artesian, originally applied to wells of this kind in which the water rose to the surface, has got to be used in a different sense, so that it may be misleading. For the original meaning the term overflowing is better, being more expressive; whilst of late years the more high-sounding name has been sometimes applied to all wells that, instead of being dug, are bored, or even only partly bored: it has become therefore little else than a constructional term, though of course a dug well, if its water

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\* *Phil. Trans.*, vol. lxxv. pp. 5, 6. (Read 1784, published 1785.)

rises to the surface, is as truly Artesian, in the original sense, as any other. The term should be limited to wells that are sunk or bored through overlying beds to a water-bearing bed, the water from which rises up to a much higher level than that at which it was found, though not needfully to the surface.

The deep wells of our district may be treated under three heads, according to the formation to which they reach, whether stopping in the Tertiary beds, reaching to the Chalk, or going below that formation.

Many years ago it was enough, even in the heart of London, to sink through the London Clay to some of the more sandy beds beneath, to get a good supply of water, and especially to the Thanet Sand. In more out-of-the-way parts, where deep wells were rare, these mostly stopped at the base of the London Clay, getting their water either from its sandy basement-bed, or from an underlying sand of the Reading Beds, or perhaps of the Oldhaven Beds. Even now, in parts of Essex, such wells are bored, a supply being got a few feet below the base of the clay, as at some of the stations along the lines of railway to Burnham etc. In the lower part of the valley of the Wandle there are many wells getting a supply from the Thanet Sand apparently, and some of these are overflowing.

In London, and in the neighbourhood, the increased demand for water led to the increase in the number of wells, and to the comparative exhaustion of the limited supply in the Tertiary sands. Many wells were therefore deepened to the Chalk, and new wells were made to that formation. The large quantity of water taken from these wells, amounting to several million gallons a day, has lowered the underground water-level in the Chalk under London, until it becomes questionable whether further well-sinking, in most parts, is likely to be successful, though there are still overflowing wells in suburban spots.

The wish of engineers and others to get pure deep-seated supplies of water has led to the making of deeper borings that come under the third heading; but, of the eight attempts made, in our district, to get water from below the Chalk, only two have been successful, at Loughton and at Mile End, where respectively Lower Greensand (possibly) and Upper Greensand have yielded a supply. At six other places, but little outside our district, a successful result has been attained at three, which are in one neighbourhood, namely at Frindsbury (two places) and at Strood. Going farther afield, to the remaining eight of the deep borings noticed on pp. 42, 43, (not counting that at St. Margarets, which was not made for water) at Holkham only was a supply got from beneath the Chalk.

Looking to the outcrops of the two formations, the Chalk and the Lower Greensand, we see some contrast. That of the former is continuous round the whole of the great tract of the London Basin, and is mostly of considerable breadth being narrow indeed only at those few places where affected by a very high dip, as along the Hog's Back of Surrey, and further westward, on the

northern side of the inliers of Upper Greensand at Kingsclere and Shalbourn. That of the latter, on the other hand, though continuous on the south of the London Basin, in Surrey and Kent, is not so on the north, and again it is, as a rule, narrower than that of the Chalk, and often much narrower: it cannot therefore give so large an area of gathering-ground as the Chalk can.

Then too in the matter of thickness the Chalk has a great advantage, the least thickness proved, from top to bottom, in the London Basin being over 620 feet, whilst the Lower Greensand probably nowhere reaches that thickness, except in places far away (as in part of the Isle of Wight), and it varies down to nothing, the formation being occasionally absent on the north-west.

It is doubtful therefore whether, if the Lower Greensand had been proved to continue underground beneath London, it would have been found to yield as much water as the Chalk, and in getting its water some difficulty might have occurred from the inflow of sand. But we know that it does not so continue, and it therefore becomes a questionable policy to sink in the expectation of reaching deep-seated Lower Greensand, except within some reasonable distance of the outcrop. That supplies may be got in such sites is likely; but that must be a matter of experiment. The borings at Richmond and at Streatham have at all events served to narrow the experimental area on the south.

It might have been expected that if, as seems likely, the Lower Greensand comes next over Jurassic limestone, or such rocks as the Richmond sandstone, at great depths underground, the water falling on the outcrop of the first might flow down into the others, and might be got from them; but we are as yet wanting in practical evidence of this, and can only hope that the Streatham boring may supply it. Neither have those older rocks as yet shown any sign of containing water of their own, from their distant outcrops.

It seems clear therefore that for large supplies of well-water in our district, and in the London Basin generally, we must look chiefly to the Chalk, and so it will not be amiss to notice some of the water-bearing characters of that formation under a separate heading.

#### *Water-supply from the Chalk.*

Our chief water-bearing beds are of two kinds, the sandy, including therein sands, sandstones, and gravels, and the limestones; this division being both lithological, according to the character of the rock, and also as to the sort of water that is got from it, which naturally depends much on the containing rock. Another division may be made however, from the texture of the rocks, whether loose, as in sands and gravels, or compact, as in limestones and sandstones, there being of course a passage between the two, nature not being in the habit of drawing hard lines of division.

Soft though it may be, the Chalk is entitled to a place among the compact rocks, and this is important, as these two classes of

beds are marked by a different method of water-communication throughout their mass. Whilst in the loose beds the downward infiltration and the underground flow of water is through the pores, so to speak, that is between the particles of which the beds are composed, in the compact rocks this occurs to a much less extent, the water finding its way instead along planes of division, of various sorts. These planes of weakness enable water to pass through rocks that one would hardly call permeable, and thus even a slate, or hardened clay, which is practically impermeable to water, may nevertheless yield a passage to it.

The Chalk perhaps holds a somewhat peculiar position in this respect; for whilst a certain amount of water may travel slowly through the spaces between the particles, as indeed may be seen to be the case in wells and adits, where a general "weeping" occurs along the sides or walls, a greater quantity probably finds an underground channel along the planes of bedding, along which there are sometimes slight openings, and which must always be planes of weakness. Still more however finds its way down and along other divisional surfaces, which have been formed after the consolidation of the rock: these are the joint-planes, formed perhaps by shrinkage, which are everywhere present, in various directions and more or less vertical, and which sometimes cause slight openings or fissures that can be clearly seen.

From this it follows, as a rule, that to get a supply of water from the Chalk, some of these fissures must be cut. Now when a boring is made the breadth of chalk cut can be measured by inches, and though, by good luck, a fissure may be cut and a good supply of water got from it; yet, on the other hand, it is equally (or perhaps much more) likely that this result may not happen; the boring is condemned, as a failure, and the water-bearing power of the Chalk is put down as small.

What then is the course that should be followed to get large supplies of water from the Chalk? Clearly a boring is not always to be depended on, and therefore the old plan of digging a well has to be resorted to, which of course increases the breadth of the work, and with it the chance of cutting a water-yielding fissure. To get very large supplies however the object is to cut many of these fissures, in fact to expose as great an amount of surface as possible, and to admit the inflow of water from as great an extent of chalk as can conveniently be got at. This of course must be done by lateral rather than by vertical extension, and the plan adopted is the driving of small horizontal tunnels (galleries or adits, as they are called) below the plane of saturation of the Chalk, and in such directions as to tap the greatest amount of water.

The subject may be illustrated in the following way. Supposing that you have an enormous cistern, full of water, derived, let us say, from the drainage of a great area of roof. If you have a small tap to that cistern, you can only get out so much water as the tap will pass, no matter how large the cistern or how great the quantity of water in it, though of course the

yield of the tap will vary with the pressure of the water. If then you replace the small tap by a large one you can thereby increase the flow of water from the cistern. If you go on to add a set of taps, so much the more water will you have at command. The small tap represents a boring, the large tap a shaft, and the set of taps a shaft with galleries.

It must be understood of course that the above remarks are of general application only : each case must stand on its own merits. There are places where borings have been successful in getting water, there are others where shafts have yielded an ample supply ; and there are some where even galleries have given but a moderate amount. To return to our cistern ! Where taps are put high up in it they command little of it, and even where these are properly placed they may be clogged. Anyhow we should complain of the taps rather than of the cistern.

From another point of view unfortunately the water-bearing power of the Chalk has been over estimated. On ordinary geological maps the outcrop of the Chalk is shown as a broad unbroken track, and it has been more or less assumed that the whole of this tract is practically available as a gathering-ground ; that is to say that over nearly the whole of it the rain falling on the ground contributes its due portion to the underground store in the Chalk. This is not really the case however ; for in many districts the Chalk is largely covered by various superficial deposits not shown on ordinary geological maps, and comparatively thin, but some of which, from their more or less clayey nature, may stop or hinder the downward passage of water into the Chalk beneath.

PROF. PRESTWICH drew attention to this in 1851, when he remarked that "over large districts . . . the chalk . . . is not bare, but is covered by an impermeable bed of a ferruginous drift clay . . . impeding almost invariably the passage of the surface water into the chalk below."\* It was only however of late years, since the Geological Survey has mapped the various divisions of the Drift, etc., that anything like a correct estimate of the areas in which the Chalk is accessible to water from the surface could be made, and still this can be done only partially.

Some years ago, this subject having been brought rather prominently before me, I constructed a set of maps, as far as the materials then at hand would allow, to show the amount of area over which rain had access to the Chalk. These were used a few years later, as the text for an address, on "Some Geological Conditions Affecting the Question of Water Supply from the Chalk," and for a paper "On the Area of Chalk as a Source of Water Supply," in the former case the treatment being stratigraphic, or according to the formations, and in the latter subjective, according to the kinds of district under consideration. For a general account of the question the reader is referred to

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\* A Geological Inquiry respecting the Water-bearing Strata . . . . Around London, p. 60.

the two papers ;\* but so far as these maps refer to our district they will now be noticed.

In one particular only do they exactly follow the Geological Map, namely in the area of bare Chalk: the four other tracts shown are not strictly geological, though depending on geology. Of these one is the tract in which the Chalk is covered by permeable beds *alone*, that is to say in which there is nothing, or next to nothing, to prevent communication between the surface and the Chalk. Another is the tract where the Chalk is protected from surface-infiltration by beds either of mixed composition or of varying character (here clay, there sand), so that communication is partly stopped, or much hindered. Yet another is the district where impermeable beds come in somewhere between the surface and the Chalk, making communication impossible, and this results of course whether the impermeable beds occur at the surface or underground. Finally it was found that this last district should be divided, there being a part of it from which the surface-waters flowed over to tracts where the Chalk was either bare, or only partially protected, notably for instance the slope of the London Clay escarpment in Hertzs., the water flowing down which sometimes sinks into swallow-holes in the Chalk (see p. 125). MR. JUKES-BROWNE remarks that this also occurs in tracts where there is a covering of Clay-with-flints, which is cut through, to the Chalk, by the valleys.

Of the sheets of the Geological Survey Map described in this Memoir two are quite out of the question here, namely 1, N.E., and 2, the tracts represented by which do not contribute a drop of water to the Chalk. One other may be disregarded, namely 1, N.W., as it represents only 2 square miles of the partially protected area with a little of the perfectly protected area draining thereto, the rest being quite cut off. The small parts of Sheets 6 and 8 with which we are dealing consist of Tertiary beds, and not of any bare Chalk; besides which the work is not yet perfected on those sheets. Consequently there are only three of our sheets that can be noticed, and the approximate measurements of the different areas in these are given below (in square miles), except that the area where the Chalk is quite protected has not been divided in the way indicated above.

Relation of Chalk to the Surface.	Sheet 1, S.W.	Sheet 1, S.E.	Sheet 7.
Chalk bare, or covered only by soil -	11	5	122
Chalk covered only by permeable beds -	23	7	86
Chalk protected by beds of mixed character -	58	20	176
Chalk protected by impermeable beds -	104	133	423
Total area (less river, part below Chalk, etc.)	196	165	806

\* *Proc. Norwich Geol. Soc.*, pt. viii., pp. 285-294, or *Geol. Mag.*, dec. iii., vol. i., pp. 23-29, and *Journ. Soc. Arts*, vol. xxxiii., pp. 847-851, or "Health Exhibition Literature."

It is hoped that, as the materials (Drift Maps) become available, the preparation of more of these "Chalk Area Maps" may go on, and it may be of interest to note here what sheets have already been done. They are 1, 3, 7, 47, 48, 50, 51, 66, S.E. and N.E.; besides which 6, 8, and 46 have been done less perfectly.

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We may now turn to another point in connection with Chalk-water, the differences between supplies got where the Chalk is at or near the surface and where it is reached beneath a mass of Tertiary beds.

In the first place it has been noticed that where the Chalk has been reached beneath a great thickness of Tertiary beds, as in many deep wells, there it seems to be less fissured than at the surface, and to yield water less freely; but as yet no thoroughly satisfactory explanation has been given.

PROF. PRESTWICH has said "It is evident, in the many movements of elevation and depression which the crust of this part of the earth must have undergone, and in the numerous earthquakes which have taken place since the land has assumed its present form, that those strata which form the immediate surface must have been far more shattered and fissured than those which are covered by a great weight of superincumbent deposits . . . Therefore, we cannot expect to find in the deep-seated mass of chalk beneath the Tertiary strata, the same facilities for the transmission of water as those which evidently exist in it where it constitutes the surface of the country."\* It should be remembered however that our bare Chalk was once covered by Tertiary beds, the removal of which, in some parts, took place in comparatively late geologic time.

The above explanation has been put in another form, namely that the great weight of overlying beds has pressed down the Chalk and kept its fissures closed. Probably there is something in this; but it has occurred to me that there may be something also in the fact that it is where the Chalk is thus thickly covered, to the extent of 200 feet and more, that it is most usually reached by boring, a process which, as aforesaid, is less likely to hit on fissures than broader work is. Where the Chalk has been reached under a somewhat lighter load, as in the Valley of the Lea, many successful borings have certainly been made, and large quantities have also been got by galleries.

It has occurred to me also, but I place no great value on the idea, that a great thickness of overlying clay is air-tight as well as water-tight, and that the air amongst the particles of chalk is unable to escape, retarding therefore the flow of the water: where, on the other hand, the Chalk is bare a natural vent-peg is provided; there is free exit for air and free channel for water. The subject is one that will bear further investigation.

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\* A Geological Inquiry respecting the Water-bearing Strata . . . around London, p. 65. (1851.)



Turning now to the question of quality, there is a marked difference in the water got from Chalk at the surface, or covered only by permeable beds, and that got from deep borings, through the Tertiary beds. It is not meant that the one water is good and the other bad; but that they are of different sorts, as judged by the solid contents, which may be readily seen by looking at the table of analyses further on (at end). This has often been alluded to, in works referring to deep wells; but as MR. R. B. HAYWARD has lately issued a special paper "On the Water in the Chalk beneath the London Clay,"\* which gives a summary of the subject, one cannot do better than quote therefrom. He says that the Sixth Report of the Rivers Pollution Commission (a valuable work on water-supply) gives 30 instances of wells in chalk, the water of which is "of apparently normal character, in which the total solid matter held in solution varies between 233 and 384 parts per million, the mean being 331 such parts; and that in these the hardness varies between  $19^{\circ}$  and  $32^{\circ}$ , the mean being  $25.8^{\circ}$  . . . . With respect to water from deep wells in the chalk beneath the London Clay [and Lower London Tertiaries] I find . . . nine instances which may be regarded as of normal character, and in these the total solid matter held in solution ranges between 330 and 840 parts per million, the mean being 672 such parts; also that the hardness ranges between  $6^{\circ}$  and  $17\frac{1}{2}^{\circ}$ , the mean being  $10^{\circ}$ ."

"A comparison of these two results at once forces on our attention the remarkable fact, that while the quantity of total solid matter dissolved is much larger on the average in the water from the chalk where it is covered by the London Clay than in that from its outcrop, and also ranges between much wider limits, yet the hardness is on the average very much less, though this also ranges between somewhat wider limits."

"This want of relation between the amount of solid constituents and the hardness of the water indicates a totally different mineral constitution in the two kinds of water."

The chief differences it will be seen, between the water of the uncovered or slightly covered Chalk and that of the deeply covered, are the replacement of lime-salts by soda-salts, and the great increase of sulphates and chlorides, and it is the decrease in lime-salts in the latter class of water that explains the decrease in hardness. The addition of magnesian and potassic salts is also notable.

The explanation of this great difference in the two sets of waters has hardly yet been given satisfactorily, and probably further investigation is needed. It may be said by some that the deep well water, from beneath the Tertiary beds, is not Chalk-water, but comes from the Tertiary sands; but if this is so it is difficult to understand how so great a quantity of water can have been got from so small an outcrop as these sands have.

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\* *Middlesex Nat. Hist. Soc.*, pp. 48-68, 1887.

Again it has been said that some of the salts, such as the sodic chloride, may be the remains of the salt of the old ocean in which the Chalk was deposited; but if so one might have expected to find them at great depths in the Chalk where it is not covered by Tertiary beds. I am inclined rather to think that, from communication between the Chalk and the overlying Tertiary sands, the water in the former has become charged with some of the saline constituents of those sands, whether original, or produced by chemical alterations going on at great depths, where the beds are saturated with water. Speaking of this view MR. HAYWARD says, in the paper above-quoted, "I should be inclined to doubt whether the quantity is sufficient to produce so widespread an effect, even if it was shewn that this would be one consequence of the mingling of these waters. It would be interesting to examine whether the softening is regularly progressive as the water passes inwards . . . from the outcrop."

If the view is right, which I am inclined to take, not so much of the passage downward of Tertiary water into the Chalk, but rather of the abstraction of saline matter from Tertiary beds by Chalk water, which water must rise, by pressure, into the Tertiary sands at great depths, wherever there is communication; or indeed if any view of purely local origin is right, one would expect that the alkaline salts should decrease by continuous extraction of the water, and MR. HAYWARD gives some evidence to that effect. He says that "the well at the Harrow Waterworks was sunk with such care to exclude the water from the sands . . . above the chalk, that there can be no doubt that we are dealing in this case with water from the chalk alone," and he notes the following general results of analyses at different times, adding that "this appears to shew a progressive improvement in the water."

In 1868.	Total solid contents	1,044.	Hardness	48·5°.
" 1870.	" " "	1,009.	"	44·4°.
" 1873.	" " "	981.	"	40·8°.
" 1883.	" " "	884.	"	38·5° or 34·3°?

The suggestion above made has the support of a good authority, for, in a paper "On the Yield of Wells sunk in the Chalk in the Central Portion of the London Basin" MR. E. EASTON has remarked on the difficulty of determining "how much of the water obtained from the wells sunk through the tertiary strata into the chalk is derived from the chalk itself, and how much from the sands between the plastic clay and the chalk. At many places the quantity from the sands is very much in excess." His "opinion is that in every well sunk in the centre of the London basin, where the chalk is covered by the tertiary sands, there is a very considerable admixture of water from these sands with the chalk water," and he concludes "that, although there is an immense surplus of rainfall percolating into the chalk all round London, comparatively little finds its way into the chalk beds beneath the centre of London; and that what does so pass is very much mixed with water which has either come direct from

the outcrop of the tertiary sands and through them into the wells, or has in its passage from the upper levels of the underlying chalk to the lower parts of the stratum gone through some of those sands. It is evident that no great quantities of water can be expected under London itself . . . and that any great addition to the general supply of the metropolis from the chalk must be looked for from the outlying districts where that stratum is denuded" [of Tertiary beds].\* The City Authorities however seem to be disposed to try for a large supply in their district.

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It would not be right to conclude this short reference to Chalk-water without noticing the work of two well-known observers, who, following in the steps of the late REV. J. C. CLUTTERBUCK, by long and careful recording of vast arrays of facts, have done so much to increase our knowledge of the water-system of the Chalk; the one chiefly by noting the minutest details of a special and important district, during a number of years; the other by extending such observations, on a more general scale, over a larger area.

MR. BALDWIN LATHAM has for a long time kept a most elaborate record of the varying levels of the water in wells over the Chalk-tract of eastern Surrey, with the neighbouring border of Kent, from which, combined with meteorological observations, he has been enabled to predict the time and place of the breaking out of the Surrey bourne, the overflow of the saturated Chalk: indeed he is almost able to trace the underground route of every drop of rain that sinks down into the Chalk in his special district, and to say when and where it will again appear at the surface!

MR. J. LUCAS has recorded the general levels of the water in many wells over a larger area, and has thus been enabled to produce a set of maps showing contour-lines of underground water-level, besides various descriptive accounts. There is no need however here to refer to these various publications in detail: those of both authors will be found entered, with the papers etc. of many other observers in this field, in a List of Works referring to Underground Water that was printed in 1888.†

When such work as that of MESSRS. LATHAM and LUCAS has been extended over the whole of our Chalk-tracts, supplemented perhaps by a corresponding extension of the Chalk Area Maps above alluded to, the study of Chalk-water will be in a fair way of becoming an exact science.

The Report of the Royal Commission on the Water Supply of the Metropolis (1869) and the Sixth Report of that on the Pollution of Rivers should also be referred to.

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\* *Proc. Inst. Mechan. Eng.* 1876, pp. 167-169.

† *Rep. Brit. Assoc.* for 1887, pp. 384-414.

## CHAPTER 29. PETROLOGICAL, MINERALOGICAL AND CHEMICAL.

THE chief part of this chapter has been written by two gentlemen, who are not connected with the Geological Survey, and it is a great pleasure to acknowledge this kindly help, whether from one who is wholly unconnected with us officially, or from one who formerly worked in Jermyn Street.

My friend MR. W. HILL has for some years spent much time in studying the Chalk; not only in the field, in making out the stratigraphical and palæontological divisions of the formation; but also with the microscope. The result of his work has been to show that different beds of the Chalk have different structures, by means of which specimens can often be distinguished under the microscope. This is not only interesting in itself, but is also of value as a means of identifying certain divisions of the Chalk from fragments brought up from deep borings, in which case naturally the ordinary means of distinction mostly fail us. MR. HILL's help in this has always been readily given.

It has been known for some time that heavy minerals, such as zircon, rutile and tourmaline, occurred in most sands etc.; but I believe that MR. ALLAN DICK, who, when Assistant in Dr. Percy's former laboratory at Jermyn Street, contributed so much to "The Iron Ores of Great Britain,"\* was the first to investigate the qualitative and quantitative character of such minerals in English sands, and chiefly from those in our present district. This subject is of interest as promising much help in tracing the original source of our sands, and perhaps it may lead to a better knowledge of their uses.

MR. R. B. HAYWARD, of Harrow, has also helped, by the contribution of the tabular statement of water-analyses. My work indeed in this chapter has been almost wholly editorial.

### THE MINUTE STRUCTURE OF THE CHALK

(by W. HILL, F.G.S.).

#### *General Account.*

Microscopic examination of the Chalk has shown it to be to a great extent organic in its origin, and the work of investigators has been hitherto chiefly directed to the classification of the minute organisms whose remains are so abundant in it.

These investigations were carried on by the examination of powdered material and of thin slices, but no special notice was taken, apparently, of the horizons from which the specimens under

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\* *Geological Survey Memoirs.* Part i., 1856, Part ii., 1858, Part iii., 1861, Part iv., 1862.

examination, were obtained: indeed, the main divisions of the formation were not recognised.

If thin slices of chalk from a large area are examined it will be seen that, besides giving evidence of its origin, it is possible to distinguish specimens from definite horizons, and the examination may assist us also in forming some idea of the conditions under which the deposit was accumulated.

When such thin slices are examined beneath an inch-objective, it is seen that a part of their mass consists of more or less perfect tests of Foraminifera, fragments of shell and, at certain horizons, mineral grains; but taking a long series of slides the greater part will be found to consist of fine material, which appears, under this power, of a structureless grey shade, in which are outlined sections of the larger elements of the rock, the Foraminifera, shell-fragments etc. This amorphous material may be called the matrix.

*The amorphous matrix of the Chalk.* Under a high power (say  $\frac{1}{10}$  in.) the edges of thin sections and the powder obtained from chalk by washing or scraping the matrix, will be found to consist of the following:—(1) particles having a definite form, as the so called crystalloids and coccoliths. (2) Minute particles which behave with polarized light as crystals of calcite, flat and large enough for their very irregular outline to be distinguished. These with the coccoliths disappear after treatment with hydrochloric acid. (3) Minute angular and sub-angular grains, some of which disappear after treatment with acid, whilst others are not affected by it. Some of these, judging from their behaviour with polarized light, are probably minute particles of quartz.

Besides these three kinds of particles, which, small though they be, possess a character by which they can be recognised, there is, in the Lower Chalk especially, a varying quantity of material of so fine a nature that its ultimate particles are hardly resolvable under the above power. This is not destroyed by the action of acid and does not depolarize light. Chemical analysis shows that where this occurs the Chalk invariably contains a high per-centage of silica. Material having the same microscopical peculiarities forms the greater proportion of clays, such as the Gault, formations derived directly from the waste of contiguous land. I therefore believe this exceedingly fine material to be inorganic and siliceous.

Its presence may be detected by a peculiar translucent appearance which it imparts to the chalk, when mounted in balsam and examined by transmitted light. It is of course impossible to estimate accurately the proportions of each kind of these particles in a given sample of chalk, but practice renders it possible to estimate by the eye whether one or the other is in excess.

*Foraminifera.* Of the larger elements which make up the bulk of the chalk Foraminifera are of the greatest interest. Taking the superficial area seen to be occupied by sections of the tests of these creatures in thin slices of chalk, it is surprising how small is their proportion to the entire mass. At certain horizons round bodies usually referred to as the disunited or primordial cells of *Globigerina* or other Foraminifera are exceedingly abundant; but, with this exception, at no horizon in this area, so far as I am aware, does any particular species exist in sufficient numbers to characterize the Chalk. The cells, as well as entire Foraminifera, vary in size and in the general robustness of their shell and figure at different horizons.

*Shell-fragments.* At certain horizons these form a large proportion of the Chalk. Minute prisms of broken shells of *Inoceramus* constitute the greater part, but portions of the shells of *Terebratulæ* of *Rhynchonella*, of *Ostrea*, and of other genera may now and then be seen. Fragments of the tests of Echinoderms occur throughout the Chalk, and at the horizon of the Chalk Rock are conspicuously abundant.

In the area under consideration the spiculæ of sponges do not occur, or occur rarely, until the Upper Chalk is reached.

*Mineral grains.* Mineral grains large enough for identification are abundant at certain horizons. Glauconite is the most common mineral, either as grains or filling the interior of Foraminifera, forming beautifully perfect casts, or filling the spicular canals, or more rarely replacing the material of the sponge-spicule or of the fragment of shell. Quartz grains are abundant in the Chalk Marl, and disappear gradually at higher horizons.

### *Chalk Marl.*

The abundant presence of shell-fragments and of Foraminifera throughout the Chalk Marl proves the deposit to be mainly organic, and suggests a source from which the fine calcareous material that forms a large part of the matrix is derived. The relative proportion however, not only of the organic constituents (shell-fragments etc.), but also of the inorganic materials constantly varies, and no specimen can be relied on as showing the kind of material occupying a particular horizon over a large area. In this area it is at the base that inorganic matter chiefly preponderates, the fine siliceous material already noticed forms a large part of the matrix, and seems to give it a bluish tint. Upward, the marl is more calcareous, and its colour becomes a yellowish-grey.

In the lower part of the marl, near Risborough, grains of quartz are exceptionally abundant and large, but they diminish in size upwards. After treatment of some of the marl with hydrochloric acid the average size of 100 of the larger quartz grains found in the residue was  $\cdot 0042 \times \cdot 0029$  inch, whilst in Chalk Marl from Herts. the average size is only  $\cdot 0025 \times \cdot 0016$ .

All the marl of this area contains glauconite in well defined grains, a fact which may help to distinguish specimens of it from grey chalk, which it may chance in other respects to resemble. They are rather small, but may generally be seen with a half-inch power.

In the hard beds which occur in the middle of the Chalk Marl and are to be seen at the spring-heads near Risborough, shell-fragments and Foraminifera form a rather large proportion of the coarser material. The matrix has however undergone a change and consists of granular crystalline calcite. This condition is more evident in some specimens than in others, a variation which is probably due to weathering. Large grains of glauconite and quartz grains are plentifully scattered through the mass. There are no sponge-spicules in any of my specimens of these beds.

### *Totternhoe Stone.*

This hard gritty chalk appears to consist of lenticular beds of varying thickness, in which shell-fragments predominate, these beds being frequently separated by less shelly layers. In that which is most esteemed for the purposes of building and is worked in the well known quarries at Totternhoe, the shelly fragments are very evenly distributed through the mass, of which they form at least 60 or 70 per cent. and they have also a great uniformity in

size. The matrix consists chiefly of calcareous particles, the fine siliceous matter being scarcely evident.

Glaucinitic grains are abundant, and beautifully perfect casts of Foraminifera, formed of this mineral, may be found. Quartz-grains occur, but they form scarcely 1 per cent. of the stone.

Specimens from the neighbourhood of Risborough and to the southward do not differ from the stone of Totternhoe except perhaps in the larger amount of the amorphous material.

### *Grey Chalk.*

This division presents a greater uniformity in its appearance, when seen in thin sections under the microscope, than does the Chalk Marl. Specimens from near its base show the greatest variation in the relative amount of coarse and fine material, but a short distance above the Totternhoe Stone it assumes a character which is retained over a wide area.

The mass of it is fine amorphous material, composed chiefly of calcareous particles, and in this matrix Foraminifera and fragments which may be recognised as those of shells can be found, but rarely in abundance.

In the upper and whiter part single foraminiferal cells are usually more numerous. At Chalkshire, N.E. of Ellesborough, they are conspicuously so. Their presence seems to give a firm but brittle character to a bed which has a considerable northerly extension and which marks more or less clearly the change from a grey to a whiter chalk.

Of the mineral grains quartz has almost entirely disappeared, minute particles which may be referred to this mineral occurring rarely. Grains of glauconite may be found near the base, in localities where the top of the Totternhoe Stone is not very clearly defined. In such and in one other locality I have found well defined glauconitic grains at a still higher horizon in the Grey Chalk, but they are not common in this division.\* Small particles, probably of shell, are sometimes seen tinted a pale yellowish-green: this usually occurs in chalk with brown rust-like stainings.

The regular character of the deposit is broken at Chalkshire (Ellesborough) by a bed of hard gritty rock locally called the "Rag." This bed consists almost entirely of shell-fragments, coarse and unevenly assorted, with but little of the finer material. Teeth and fragments of bone are very common and grains of glauconite occur, but no quartz. The green-coated nodules so abundant in the bed are of similar material to the lower and greyer part of the Grey Chalk. The holes by which all are pierced are mostly filled with the coarse shelly material which now surrounds them.

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\* This holds true for the counties of Buckingham, Bedford, Hertford and Cambridge; but, since the above was written, I have found that grains of glauconite and of quartz pass up into the Grey Chalk, at many places in Berkshire and Wiltshire.

*Belemnite Marls.*

In the grey marly bands which occur at the top of the Grey Chalk the coarser particles, shell-fragments, and Foraminifera, though varying in their relative proportions, often form half the deposit. The shell-fragments are rather small, as compared with those of the Grey Chalk, from which they may possibly have been derived: the Foraminifera are chiefly singly cells.

Small lumps or nodules which from their structure appear to be derived from the upper (white) part of the Grey Chalk are sometimes included in the lower marl-band, and are so numerous at Chalkshire as to give a mottled appearance to the bed.

Between the two bands of marl there is generally a bed of hard white chalk, the structural characters of which are remarkably constant; single foraminiferal cells form at least 70 per cent. of this, the remainder being amorphous matrix; and shell-fragments are comparatively rare. This bed of hard white chalk is occasionally replaced by hard gritty material consisting chiefly of comminuted fragments of shell, and embedded in this are angular and rounded fragments of chalk, exactly like that of the hard white chalk which is replaced. It would seem probable that the white chalk was once continuous, but has in some localities been broken up, fragments only being left to tell of its former existence. No exposure of the bed in its broken-up condition occurs in this area, but specimens of chalk met with in the Richmond boring at a depth of 702 feet bear every resemblance to the nodular bed which occurs at this horizon in Hertfordshire and Cambridgeshire.

*Melbourn Rock.*

The change from the Lower Chalk, in which, as a rule, Foraminiferal cells and shell-fragments are comparatively rare, to chalk which contains these ingredients in exceptional abundance, is abrupt and the difference between the two kinds of rock, when thin slices are viewed beneath a microscope, is striking. This change and contrast seems to be persistent from the Isle of Wight, on the south, to Speeton in Yorkshire, on the north, and to Dover, on the east. It should lead to the easy detection of the base of Middle Chalk where a sufficient number of specimens are taken during the progress of a boring through the formation.

The Melbourn Rock is not homogeneous, like the beds hitherto described, but consists of closely packed nodules or lumps of compact white chalk, set in and cemented together by a greenish-grey marly material which contains a large amount of coarse shell-fragments. Smoothed hand-specimens from the lower part of the rock appear as white chalk marbled by veins or mottlings of greenish-grey. These veins seem more or less clearly to define the limits of irregularly-shaped lumps or nodules, and are easily traced in thin sections by the more abundant presence of the coarser fragments of shell.

The nodules thus defined present some variety of structure and may be compared with fragments of Grey Chalk or of the hard



white bed which occurs at the horizon of the Belemnite Marls. There seems to be every gradation in the definition of the individual nodule, from a well-defined sharply-angular fragment to the nodule whose shadowy outline blends with, and is scarcely traceable in, the mass of the chalk. In size they vary greatly, from a minute particle not larger than a pin's head (but whose sharply-angular outline is clearly defined, by the coarse shell-fragments which surround it) to the rounded lump to which young oysters may be found adhering. This structure of the Melbourn Rock suggests that the chalk at this horizon, while only partly consolidated, has been broken up and re-arranged.

In the upper and yellower part of this Rock the nodules are less numerous and more clearly defined. The matrix in which they are embedded usually contains, as before, a large proportion of coarse shell-fragments, but specimens from various localities differ in this particular.

#### *Middle Chalk.*

With the decrease in the proportion of shell-fragments, at the top of the Melbourn Rock and in the chalk overlying it, the single foraminiferal cells become correspondingly abundant, and in the zone of *Rhynchonella Cuvieri* they form a large part of the chalk. At no other horizon are they so uniformly abundant and so robust in their appearance. But it would appear that the waters of the Chalk-sea gradually ceased to afford these minute creatures conditions suitable to their development, for the cells become less and less numerous and robust till, in the zone of *Terebratulina gracilis*, they cease to be conspicuously abundant, and fine amorphous material with few shell-fragments constitutes the mass of the chalk. But again they gradually increase, and some 20 feet below the Chalk Rock the cells form nearly half the deposit, though they scarcely regain their size and robust appearance.

Throughout the Lower and the Middle Chalk Foraminifera other than the single cells constantly occur, but the space occupied by their tests is insignificant when compared with the mass of the chalk. Judging only from the outline of the tests when seen in section the commonest forms may be referred to *Globigerina*, *Rotalia*, *Cristellaria*, *Textillaria* and *Lagena*.

#### *Chalk Rock.*

For identification by means of thin sections viewed under the microscope the Chalk Rock is perhaps one of the best marked horizons of the chalk. The peculiarity of the structure lies in the variety of organic remains with which the rock is crowded and in the presence of large grains of glauconite.

This structure comes on gradually; first, as already noted, by the increase in the proportion of single Foraminiferal cells, then from the increase in shelly fragments, many of which appear to be portions of the test or spines of echinoderms, their conspicuous abundance being peculiar to this horizon. Foraminifera increase in number and in variety, and sponge-structure and detached

spicules are constantly met with. Large grains of glauconite are abundant and this material may also be seen filling the canals of sponge-spicules and the interior of the tests of Foraminifera. Finally the whole matrix becomes crowded with organic particles, showing a variety of structure, and with Foraminifera.

No one who has seen a slide prepared from that part of the Rock in which Gasteropods are common will mistake it for chalk from any other horizon.

The green-coated nodules which abound in the Chalk Rock present much the same appearance as specimens of the Rock from which they come, but the proportion of the amorphous material is usually greater and the identifiable particles are more widely separated.

### *Upper Chalk.*

Above the Rock its characters speedily disappear. Specimens of the Upper Chalk from Taplow consist almost wholly of the amorphous calcareous matrix with very few Foraminifera or fragments which can be recognised as of shell.

MR. HILL's remarks on specimens from various deep borings will be found in the descriptions of those borings, in the Appendix on Well-sections.

## THE DENSER MINERALS IN SANDS AND CLAYS

(by ALLAN B DICK).

### *General Remarks.*

Some time ago when it appeared probable that Zirconia would become of practical importance for illumination I examined a number of sands and clays, for the purpose of ascertaining the per-centage of zircons contained therein, and the result of that investigation was published in *Nature*.\* Amongst the sands examined attention was principally confined to the finer grained ones, nearly free from hydrated oxides of iron. Such deposits exist on a large scale amongst the Bagshot Sands; but many other sands were examined.

It was found, as might have been expected, that the sands varied very much; the proportion of minerals over the density of 2.86 ranging from a very small per-centage up to about 4 per cent. as under.

### *Percentage of Dense Minerals in Samples of Sand.*

Bagshot Sand from High Beech Reservoir	-	4.0
„ another sample from High Beech	-	1.32
„ Hampstead Heath	-	3.86
„ another sample from same deposit	-	3.60
„ from cutting in making new road near the Fire Engine Station, Hampstead	-	1.04
„ near Otterbourn, Hants.	-	0.12

\* Vol. xxxvi., no. 917, p. 91. (1887.)

The dense minerals were found to vary greatly in their relative proportions, but all contained zircons and some in such quantity as to give a reasonable hope that their extraction might prove as profitable as the washing of alluvium for tin-ore. Whether this would be so or not must be left for settlement by those who hope to make a profit thereby.

Mr. Whitaker, who supplied me with many samples of sand, having asked me to give a short account of the matter for this *Memoir*, I do so with pleasure, prefixing at his request a few remarks about appliances for the investigation of sands and clays.

### *Method of Examination.*

For the qualitative investigation of such sands I have found nothing better than a rather flat white saucer the central part of which is quite flat. If the same saucer is always used the investigator soon acquires great skill in its use. By a circular movement in such a saucer, about one third full of water, the sand is easily separated into a lighter and a denser part, each of which can be examined separately under the microscope. About half a thimble full of sand is enough to use. If the sand proves to be rich in dense minerals a larger trial may be made on a sieve like an ordinary kitchen cullender, the bottom of which has been taken out and replaced by fine but stout muslin. I found a cullender about 12 inches in diameter, the bottom of which was made with an ordinary handkerchief, a satisfactory appliance for washing two or three pounds weight of sand. The bottom of the sieve should be only thinly covered each time. By a rolling motion under water the dense minerals quickly pass through the meshes mixed with some sand. The water should not wash over the frame of the cullender. The minerals will go through a sieve which apparently should stop them, but the meshes no doubt open to let the minerals through. On a larger scale a suitable "Loo" or jigger could be used, or even a round buddle, but with a cullender such as described an ounce of the dense minerals, mixed with about its own weight of sand, is obtained from the work of an hour. The work may be done either in air or water, on the same sieve; but in air much more sand passes through the meshes with the dense minerals.

For quantitative trials the boro-tungstate of cadmium is much preferable to Sonstadt's solution.

A binocular microscope, with polarizing apparatus and a half-inch objective of low angle, is suitable for the examination of sands. If the objective is fitted with a Lieberkuhn and the substage with a spot-lens of adjustable focus it will leave little or nothing to be desired.

It may be here noted that when the particles of sand or clay are very small, separations by density give only approximate results, and often no separation can be thereby effected. Thus the smaller crystals of rutile, zircon, tourmaline, &c. are floated away in water with clay, and settle with it when left at rest. The same takes place in dense solutions. I persevered for many days in trying to separate feldspar from quartz in Hampstead sand, where the grains are under the  $\frac{1}{100}$  of an inch in diameter, though there is no difficulty in separating larger grains of those minerals. Eventually I had to fall back on analysis, and from the alumina found to deduce the amount of feldspar. This it must be allowed is eminently unsatisfactory, as it must be borne in mind that many of the feldspars are more or less, and some completely, kaolinized. This further vitiates such a manner of estimating feldspar in sands and clays, which I am obliged to leave as a very open question.

### *Results.*

In *Nature* I gave the following as an approximation to the mineral composition of a large deposit of sand on Hampstead

Heath, but separating the quartz, felspar and clay, which are now grouped together for the reasons above given.

Quartz and felspar, with one or two per cent.			
of flint fragments and about one per cent.			
of clay	-	-	96 per cent.
Grains attracted by a strong magnet	-	-	about 2 "
Zircons in recognizable crystals	-	-	" 0.5 "
Grains more or less opaque, probably zircons	-	-	" 0.25 "
Rutiles	-	-	" 0.20 "
Tourmalines	-	-	" 0.01 "
Other grains, mostly opaque and of various colours	-	-	" 1 "

Amongst these grains, though forming no appreciable part of the weight of the sand, may be mentioned flakes of topaz and angular fragments of garnet. The latter are very common in some of the Bagehot Sand about Weybridge. I met with only one good crystal of anatase in the Hampstead sand but it occurs more abundantly in some of the sands at Alum Bay and in very small crystals in the London Clay. Many dense grains without definite crystallographic shape, in all sands and clays, consist, I think, of anatase but where the form is wanting it is impossible to form a definite opinion. Apatites, so common in many rocks, are rare in sands and clays, which may be due to the solvent action of water. I have been unable to find a single crystal of it, except a few as enclosures, in Hampstead sand. The smaller crystals of apatite can be distinguished from small tourmalines only by the action of acid, in which the latter are insoluble, though where the crystals are thick enough to show colour in polarized light there is no difficulty, even when the tourmalines resemble rubellite in having little or no power of absorption. Cassiterite I failed to find in any sand, though much time was spent in trying to do so.

Since the account in *Nature* was published I have examined the grains attracted by a strong magnet. It weighed about 20 lbs., was of compound construction, and magnetised to the utmost. A smaller electro-magnet would have answered equally well, as I have since found. It should be strong enough to attract tourmaline. From about  $\frac{1}{2}$  an ounce of the black grains I got only a few grains by the influence of a small magnet, but one strong enough to attract magnetite with avidity.

It thus appears that the Hampstead sand is nearly or quite free from magnetite. Whether this has been due to its removal by air and water or whether it was absent from the parent rock is doubtful. Slightly ferruginous springs break out here and there at the junction of the sand and the London Clay. The ferruginous character of the water may arise from the small remainder of magnetite, or from pyrites if any is present, but none was found. In the London Clay itself round Hampstead I found magnetite, but whether that is due to the fact that water does not so easily pass through clay or whether the clay was derived from a rock containing more magnetite, there is no clear evidence. In both the greater part of the black grains were found to consist of ilmenite, but the London Clay contained a considerable proportion of magnetite. I have since found ilmenite to be a common ingredient of sands

and clays. Unfortunately I have mislaid or lost the record of my analysis of the black grains, but it was found that 97 per cent. of the grains were decomposable by hydrofluoric acid and that those consisted of ilmenite, containing as usual a little manganese and magnesia, both I think under 2 per. cent. The grains are more or less flattened, black and lustrous, as though they had just been broken from the parent-rock. About 24 hours were allowed for their decomposition by cold hydrofluoric acid. The part insoluble in hydrofluoric acid consisted of black grains, many of which were perfect octahedra or modifications thereof. When these were crushed beneath the glass cover of a microscope-slide it was seen that the fragments transmitted light of various colours, deep red (chromite), bluish, greenish and brownish. I suppose them all to be spinels of various composition, but I have not analysed them: possibly some may be specular iron, which is almost insoluble in the acid used, as was found by trial on grains of equal size to those in question. Chromium was the only thing sought for and I found it easily, but it is only a minority of the grains which transmit the deep red light of chromite. Mixed with the black grains left by hydrofluoric acid were many zircons containing enclosures of magnetite, by virtue of which they had been attracted to the magnet in the first instance.

I tried a number of methods of separating the zircons and rutiles. It is known to be very difficult to separate titanic acid and zirconia when together in solution, so my endeavour was to separate the minerals rather than their constituents. It does not seem to be difficult by the action of various salts of potash and soda at a red heat, the rutiles being easily attacked and titanates formed. For instance, about 10 grains by weight of the minerals, the density of which exceeded 3.2 (after removal of the ilmenite &c. by an electro-magnet and of some of the lighter opaque grains by vanning) were fused with 4 times their weight of neutral sulphate of soda, to which 5 grains of carbonate of soda had been added. The fusion was continued for about half an hour, at a low red heat, the fused mass was digested in water, to remove as much of the alkalies as possible, and the residue was digested in hydrofluoric acid; whereby, after further washing in water by decantation, about 7 grains of zircons, mixed with a few flakes of cyanite, were obtained. The zircons had been attacked only on the surface of the crystals or not at all. A practical separation was also brought about by fritting such a mixture with a much smaller weight of the alkaline matters, maintaining the heat for 5 minutes, or even much less, whereby the rutiles were covered with a husk of more or less insoluble titanates. The total residue after soaking in water was washed by decantation in the saucer already described, so that the rutiles, enveloped in their lighter coverings, were easily washed away from the zircons, which did not seem to have been at all corroded, even on their surfaces.

### *Life of the Crystals.*

The endurance of these small crystals is astonishing. They may be well studied by breaking up any rock (such as granite) containing them. A steel mortar is the best appliance and the powder should not be ground in a mortar, only sifted out from the larger fragments. The artificial sands so produced will be found to contain the zircons, rutiles, spheens, tourmalines, apatites, &c., either whole

or broken, generally into only two or three fragments, exactly as they are found in natural sands. For instance, on the beach at Alum Bay, in the Isle of Wight, it will be found that the zircons, rutiles, &c. do not differ from the same minerals in the sand-cliffs above, and from which the sands have been derived. Many crystals, indeed the majority, are more or less rounded; but, if that has been done by water, it must have been on some previous occasion. One is tempted to speculate on the number of times a crystal of zircon has entered into the composition of a rock; since the crystal was first formed. Too small to suffer much, if at all, from attrition in water, and almost as little affected by air and moisture as the diamond, they seem fitted for an existence of indefinite duration under ordinary circumstances. Amongst the earlier formed crystals in an igneous rock, they are found unchanged in the sands and clays derived therefrom. They suffer no change during the consolidation of those sands and clays into rocks, nor even during their subsequent metamorphism; zircons differing in no respect from one another may be seen in sandstones far from igneous rocks, and in others so near the junction that the sandstone has lost its character through partial fusion. In the sands and clays arising from the destruction of the metamorphosed rocks the like small zircons again appear, as in the Bagshot Sand of the cliffs at Alum Bay. Yet once again they reappear in the sands forming on the beach, which sands in due course may and probably will be consolidated and metamorphosed, enclosing the same zircons which have endured throughout those changes, with indefinite intervals of time between each change of position.

#### MINERALS.

To the mineralogist the London Basin has little interest, but nevertheless it may be as well to give a list of the few minerals found in our district, and to notice their distribution in the various formations.

I have to thank my friend MR. H. BAUERMAN for looking over the following account, when it was prepared for vol. iv. of the *Memoirs*.

*Carbonate of Lime*.—Whether in the form of calcite or aragonite, this, one of the commonest minerals, is comparatively rare in the London Basin. I believe that crystalline carbonate of lime is sometimes found in the Chalk, and the fossils of that rock are mostly composed of it. It also occurs in the septaria of the London Clay, but only in very small crystals, slightly discoloured by iron.

The springs of the Chalk sometimes deposit *tufa*, which quickly coats twigs, &c. in the streams. One of these springs is noticed at p. 61.

*Sulphate of Lime*.—Crystals of *selenite* are of common occurrence in the London Clay, often of large size and well-defined; both in simple forms, macles, and radiated masses. They are always more or less coloured by the clay, but often are fairly translucent, so that workmen now and then call them "petrified water."

In the clays of the Woolwich Beds small crystals sometimes occur, and also fibrous gypsum. At some places the sulphate of lime has been dissolved out, and only the impressions of the radiated masses left.

*Sulphate of Baryta* has been found in very small quantity in some London Clay fossils.\*

*Epsomite* (sulphate of magnesia) "occurs in an efflorescent state at Epsom."†

*Allophane*, a hydrated silicate of alumina, occurs at the junction of the Thanet Beds and the Chalk near Woolwich, and its occurrence and formation have been described by PROF. MORRIS.‡ Its probable occurrence near Northaw has been noticed by MR. PRESTWICH, and I have also found a little of it (or of some like mineral) at the same junction at Chiselhurst and, beyond our district, at Faversham.

*Glauconite*, or green-earth, is probably the colouring-matter of the green sands that are found in the various Tertiary beds.

*Iron-pyrites* (both the cubical variety and *Marcasite*) is of constant occurrence. In the Chalk it is usually in a radiated form, either cylindrical (with rounded ends) or spherical. In the Woolwich Beds it now and then forms sharp casts of shells, and at Loam Pit Hill, near Lewisham, I have found specimens of *Melania inquinata*; with all the characteristic markings, wholly composed of this mineral.

*Vivianite*, or blue phosphate of iron, is found in some alluvial deposits, for instance in the valley of the Thames, in small specks on bones or horns.

*Amber* has been found on the coasts of Essex and Kent, and "in sand at Kensington."§

*Copaline*, or *Highgate Resin*, is occasionally found in the London Clay at Highgate, and at a few other London localities (see p. 258). Its occurrence in the same formation at Richmond is recorded by DR. J. WOODWARD in the quaint Catalogue of his Fossils.

*Lignite* occurs sometimes in the Woolwich Beds (see pp. 133, 154), but only in a thin bed and impure.

#### GASES IN THE CHALK, &c.

Many years ago DR. J. MITCHELL read a paper to the Geological Society on this subject, the chief part of the abstract of which may well be reproduced.

"In the chalk the most abundant deleterious gas is the carbonic acid, but it has been found to exist in greater quantity in the lower than in the upper portion of the formation, and in that division to be unequally distributed. In sinking wells, it has been noticed to issue with force from one stratum, whilst none has been perceived to be given out from the beds immediately above and below it." He notes "fatal effects due to its occurrence in a well near the race-course at Epsom," 200 ft. down; "and in Norbury Park near Dorking," 400 ft. down. "On Bexley Heath, after sinking through 140 feet of gravel and sand, and 30 feet of chalk, it rushed out and extinguished the candles of the workmen; and in making a well in Long Lane, Bexley Heath, after penetrating 124 feet of overlying deposit and then 90 feet of chalk considerable inconvenience was felt from it, but 6 feet lower no gas was emitted."

"In chalk, sulphuretted hydrogen gas is also occasionally met with, and is supposed to be generated from the decomposition of water and iron pyrites."

\* N. T. WETHERELL, *Ann. Nat. Hist.*, ser. 2, vol. viii. p. 378. (1851.)

† GREG and LETTSON's *Mineralogy of Great Britain and Ireland*, 1868 p. 70.

‡ *Quart. Journ. Geol. Soc.*, vol. xiii. p. 18. (1857.)

§ GREG and LETTSON's *Mineralogy of Great Britain*, p. 9.

"In districts in which the chalk is covered with sand and London clay, carburetted hydrogen gas is sometimes emitted, but more frequently sulphuretted hydrogen gas."

"Carburetted hydrogen has seldom inflamed in wells, but in making the Thames tunnel it has sometimes issued in such abundance as to explode by the lights and scorch the workmen."

"Sulphuretted hydrogen gas is more abundant, and it has been observed almost always to proceed from a coarse black sand charged with oxide of iron . . . It has streamed out with great violence in the Thames tunnel, but has in no instance produced fatal effects. At Ash, 3 miles from Farnham [beyond our district] a well was dug in sand to the depth of 36 feet, and one of the workmen on descending into it was instantly suffocated. Fatal effects have also resulted from the accumulation of this gas in wells in Maiden-lane, Battle-bridge, and at Applebury-street near Cheshunt. This gas is much increased, after long-continued rain, in consequence of the swelling of the clay driving it out of the interstices; and it is diminished after a long drought."\*

#### ANALYSES.

##### *Chalk.*

By MR. W. J. WARD (late of Dr. Percy's Laboratory, at the Geological Museum, Jermyn Street) of a sample, selected by him on the spot, as a fair average sample of the Chalk in Messrs. Francis and Co.'s quarry, Cliffe Creek [Upper Chalk].

Communicated by MESSRS. FRANCIS.

The sample contained 20·61 per cent. of Hygroscopic Water. It was dried before analysis at a temperature of 212° Fahr.; and the total amount of lime in the dried sample was 55·25 per cent.

Carbonate of lime	-	-	-	98·52
Carbonate of magnesia	-	-	-	·29
Sulphate of lime	-	-	-	·14
Peroxide of manganese	-	-	-	·04
Peroxide of iron, with a little alumina	-	-	-	·4
Phosphoric acid	-	-	-	trace.
Organic matter	-	-	-	trace.
Ignited insoluble residue, chiefly silica	-	-	-	·65

100·04

##### *Woolwich and Reading Beds.*

Green sand from the upper part of the Bottom-bed. From the cutting on the Railway, through Park Hill, Croydon (see pp. 130, 131).

By DR. HODGKINSON. *Proc. Geol. Assoc.*, vol. viii., no. 4, p. 230. (1883.) Mean of 3 analyses.

Silica (insoluble)	-	-	-	92·
Oxide of iron, with a little alumina and oxide of manganese	-	-	-	6·2
Loss on ignition. Water, partly of hydration	-	-	-	1·93

100·13

\* *Proc. Geol. Sec.*, vol. iii., no. 65, p. 151. (1839.)



"These figures seem incorrect, but the substance contains iron in the lower state of oxidation, and thus gains weight on being heated in contact with air. . . . The silica is present partly as quartz particles, partly as a silicate of ferrous oxide, or as glauconite. Calcium and magnesium are only present in very small amounts."

Mottled clay, from the same section section, *Ibid.*, p. 233.

Silica	-	-	-	-	-	47.7
Oxide of iron, as $\text{Fe}_2\text{O}_3$	-	-	-	-	-	15.76
Oxide of manganese	-	-	-	-	-	.12
Alumina, in the form of aluminic silicate	-	-	-	-	-	23.36
						<hr/> 86.94
Moisture, lost on drying at 100° C.	-	-	-	-	-	6.36
Water of hydration, lost on further heating to redness	-	-	-	-	-	7.39
						<hr/> 100.69

The following chemical analysis of a sample from the lower part of the shelly clay, which crops out in the grounds of Bromley Palace (southward from the house) was made for MR. COLES CHILD, to whom I am indebted for a copy, by MR. J. C. NESBITT.

Carbonate of lime	-	-	31.767
Siliceous matter	-	-	25.372
Moisture	-	-	20.693
Oxide of iron and alumina	-	-	13.053
Hydrated sulphate of lime	-	-	4.558
Organic matter, &c.	-	-	2.948
Carbonate of magnesia	-	-	1.431
Phosphoric acid	-	-	.178
			<hr/> 100.
Nitrogen (equal to)	-	-	.045
Ammonia	-	-	.055

### London Clay.

An analysis, presumably of London Clay, is given in GOODWIN'S "Account of the Neutral Saline Waters at Hampstead,"\* thus:—

"One hundred grains of clay [from near the spring] afforded":—

Silica	-	-	64 grains.
Alumina	-	-	26 " by estimation.
Sulphate of magnesia	-	5	" "
Oxide of iron	-	1	" by estimation.
			<hr/> 96

"besides a very small proportion of carbonate of lime and waste."

The following analysis of London Clay, from Regent's Park, was made by PROF. WAY†:—

Organic matter and combined water	-	5.47	} 100
Sand	-	12.35	
Clay	-	79.39	
Lime	-	2.79	

\* 8vo. Lond., 1801, p. 43.

† From a pamphlet on Sewerage by J. B. DENTON, p. 49.

Analysis, by MR. PORRETT (in 1811), of cement-stone (London Clay septaria) from Southend. Dried at a heat of 400°. From COL. PASLEY, "On Limes, Calcareous Cements, &c." 8° Lond., 1838. Appendix, p. 112.

Carbonic acid	-	29·77
Lime	-	34·08
Silica	-	12·
Alumina	-	13·
Magnesia	-	1·52
Black oxide of iron	-	8·8
Loss	-	·83
		<hr/>
		100·
		<hr/>

Analysis of specimens of nodules from the London Clay at Highgate, by R. PHILLIPS, *Lond. Geol. Journ.*, p. 17. (1846.)

Phosphate of lime	-	59·4
Carbonate of lime	-	17·16
Silica	-	8·08
Alumina	-	4·8
Oxide of iron	-	6·
Carbonaceous matter	-	·92
Moisture	-	3·2
		<hr/>
		99·56
		<hr/>

#### *Alluvium.*

The table on the following page has been made from a selection of analyses of specimens from the excavations for Tilbury Docks, and it refers to the various beds of marsh-clay, in downward succession, as given on p. 467.

*Analyses of the Alluvial Clays of Tilbury Docks.* By W. JOHNSTONE. 1885. For the general section here see p. 467.

A = soluble in Acid. B = insoluble in Acid. C = Total.

	Uppermost Marsh-clay (1 of general section) below the discoloured part. 5 or 6 feet below the marsh-level.			Probably uppermost marsh-clay. 7 about 8 feet below marsh- level.			Marsh-clay above main peat-bed (3 of general section). About 15 feet below marsh- level.			? From 3 or 5 of general section. About 20 feet below marsh-level.			Marsh-clay below the main peat-bed (5 of general section). About 30 feet below marsh-level.			From lowermost marsh clay (7 of general sec- tion). 40 feet below marsh-level.		
	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
Silica . . . . .	—	59·61	59·61	—	62·08	62·08	—	56·13	56·13	—	65·15	65·15	—	57·19	57·19	—	57·03	57·03
Alumina . . . . .	·93	6·77	11·7	3·06	7·56	10·63	7·04	9·7	16·74	1·98	7·14	9·08	5·35	6·95	12·3	5·63	7·	12·63
Oxide of iron . . . . .	8·	·86	8·86	6·3	1·25	7·56	9·6	1·02	10·63	5·46	1·2	6·66	7·55	1·6	9·15	7·88	1·82	9·7
Lime . . . . .	7·1	1·43	8·53	7·77	·3	8·07	4·2	1·35	5·55	9·8	1·13	10·93	10·94	·56	10·8	8·87	·62	9·49
Magnesia . . . . .	·53	·53	·86	·6	·05	·65	·42	·3	·72	·21	·22	·43	·16	·04	·2	·56	·47	1·03
Sulphuric acid . . . . .	3·62	—	3·62	·96	—	·96	3·56	—	3·56	2·21	—	2·21	2·17	—	2·17	1·11	—	1·11
Sodium chloride . . . . .	trace	—	trace	1·36	—	1·36	1·93	—	1·93	·85	—	·85	·76	—	·76	·43	—	·43
Alkalies . . . . .	·96	3·08	2·98	·4	1·94	2·34	·78	3·57	3·35	·55	3·13	2·68	·99	1·3	2·29	1·33	·17	1·5
Carbonic acid and loss . . . . .	3·84	—	3·84	6·36	—	6·36	1·4	—	1·4	2·07	—	2·07	5·14	—	5·14	7·11	—	7·11
Total . . . . .	28·98	71·02	100	26·81	73·19	100	28·93	71·07	100	28·03	76·97	100	32·38	67·62	100	33·9	67·1	100
Moisture . . . . .	—	—	38·91 per cent.	42·5 per cent.	—	—	50·40 per cent.	—	—	27·87 per cent.	—	—	35·98 per cent.	—	—	38·14 per cent.	—	—
Organic matter and water of combination. . . . .	—	4·96	—	3·14	—	—	4·23	—	—	4	—	—	3·56	—	—	4·29	—	—



**GEOLOGI**

ALBANY COUNTY (ALBANY AND HENRIETTA, WATER DIST.).	
Harrow Waterworks (mean of Wanklyn, 1881 ; Living, 1882 ; Bloom, 1883.	
85	884
—	—
89	68
19	58
37	170
18	—
05	211
13	267
36	123
—	—
8	23
16	—
1	20.0
1	18.5
1	38.5

100000 of C

*Water from Wells.*

In his paper above-quoted (p. 514) MR. HAYWARD reduced the analyses of the mineral and other contents of 16 well-waters to one common form, so that comparison could readily be made. This seemed to me so convenient that I resolved firstly to reproduce it, and secondly to ask MR. HAYWARD to extend it. He has kindly done so, by reducing the analyses of the water from many other wells, which I sent to him, to the same form.

The whole has been put together, with some rearrangement, in the accompanying table, which, though without doubt capable of extension, is probably a good illustration of the remarks that have been made in the foregoing chapter (pp. 514-516).

MR. HAYWARD writes that "the analyses from which the table has been reduced are, in many instances, incomplete, but an endeavour has been made to extract from them all the positive information they contain."

Many analyses of the well-waters of the Kent Company have been made, by DR. TIDY,\* by DR. FRANKLAND and by DR. BERNAY.†

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\* The London Water Supply. London, 1878.

† Sir F. Bolton's London Water Supply, 1884.

## SUPPLEMENT.

*Thanet Sand.*

MISS M. I. GARDINER has given a detailed description of "The Greensand Bed at the Base of the Thanet Sand,"\* from which the following remarks are taken, the specimens referred to being however mostly from places beyond our district.

The author says that "this basement-bed is a very fine sand formed of about equal quantities of dark and light[-coloured] grains mixed with more or less clayey matter. Its appearance in a section varies considerably with the weather, for it is the dark greenish grey of the darker grains which gives the colour when it is wet; but when it is dry the clayey matter becomes a white powder, and is a much more conspicuous constituent. A microscopic inspection shows the sand to consist of quartz, flint, glauconite, and small quantities of felspar and various rarer minerals, with a few casts of microscopic organisms."

"*Quartz*.—The quartz is in not much rounded grains of average largest dimensions about .1 millim. One of the striking points about the sand is the small proportion of quartz-grains, namely, only about 45 per cent."

"*Glauconite*.—The glauconite-grains are small as compared with those of most greensands. The majority are of rounded outline, and consist of an aggregation of smaller grains, often wedge-shaped in form and fitted together in a convolute manner. The cracks between the parts of the grain are marked by a yellow line [plane], probably of iron-oxide. This kind of aggregate seems to be the commonest form of glauconite-grain, and occurs in those of the . . . basement-bed of the Woolwich Sands. Other green grains are subangular. Some of these are only pieces of the round grains, but others are probably coated grains of flint or quartz . . . The glauconite-percentage is only 15."

"*Flint*.—On first looking at a slide of this sand one is [mentally] struck by the large number of very sharply angular chips. These may be roughly divided into two sets, the one transparent, the other almost or entirely opaque." Of the former "their close resemblance to chips obtained by crushing a flint seemed to leave little doubt as to their nature," and further examination "seems to leave no doubt that these lighter grey grains are flint, although they form the abnormally large proportion of 20 per cent."

With regard too to the more opaque grains "The evidence there is seems to be in favour of the supposition, suggested by their form, that these grains are also flint. Counting these in with the others, the flint-percentage rises to 40. This and the other percentages have been obtained by counting between 3,000 and 4,000 grains. The flint-grains are of about the same size as the quartz-grains. . . ."

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\* *Quart. Journ. Geol. Soc.*, vol. xliv. pp. 755-760. (1888.)

"It is these opaque grains quite as much as the glauconite which give the dark colour to the sand . . ."

"Besides these flint-grains, larger ones which might almost be called small pebbles, about  $\frac{1}{8}$  inch in diameter, are often found, and at Pegwell Bay much larger flints, some slightly rounded like those just above the chalk, and others which are regular pebbles."

Of other constituents twinned felspar "occurs in no great quantity" and "probably both magnetite and a dark spinel are present."

"Zircon also forms a large proportion of the heavier minerals. It occurs in very perfect crystals and in grains. The crystals differ considerably in size and form . . ."

"Garnet (?).—In about the same quantity is present a mineral of which only broken fragments of fairly large size have been seen . . . The fragments are often very sharply broken . . ."

"Rutile is not present in such quantity as the minerals already described . . . It is in long narrow prisms and grains."

"Tourmaline is present in about the same quantity," of various colours, and sometimes "in small and very perfect crystals . . ."

Actinolite, epidote, and chalcedony "occur in very small quantities."

"A few microscopic organisms have been met with, and are sufficiently numerous to render it probable that with careful searching many genera might be found. The commonest are siliceous, spherical bodies with a pitted surface, with a more or less distinct dark centre, apparently not casts. These may be either Radiolarians or Diatoms. Casts of Foraminifera, probably of the genera *Planorbulina* and *Textularia*, in a clear, colourless mineral, perhaps chalcedony, have been noticed."

The chief interest in the above seems to be the very large amount of flint-fragments found, such being rare in sand, as a very general rule. The author alludes to the bearing of this discovery on the question of unconformity between the Chalk and the Thanet Beds, as follows.

"Although a small flint-percentage might be due to an unconformity at a distance, so large a percentage could hardly have occurred in a sand formed far from the source of the flint; because the further the flint was carried, the greater would be the chance that, when deposited, it would be mixed with sand from other coasts. If such a sand could only be formed close to a chalk-shore, its existence at the base of the Tertiaries forms an additional piece of evidence in favour of the gradual extension of the earlier Tertiary sea described by Prof. Prestwich." [Geology, vol. ii. p. 337.]

"One at once wonders how so large a flint-percentage could have been formed in early Tertiary times, whilst the sand now being formed along a very similarly situated shore contains little or no flint. The difference may, perhaps, be due to a difference in the nature of the coasts" [in which case however there can hardly be a "similarly situated shore"] or, in other words, that



the Tertiary sea may have beaten against "something like 200 miles of unbroken chalk-cliff along its western shore."

The absence however of flints in the Thanet Beds, except for the thin layer at the base (which shows little sign of transport, and may have resulted mostly from dissolution of the Chalk, as, noticed on p. 105) and the rarity of rolled flints even in this layer, are factors that have to be taken into consideration, as well as the absence of any remains of a chalk-cliff of the age of the Thanet Beds.

#### *River Drift.*

With regard to the "occurrence of a tooth of the Blue Shark (*Carcharias glaucus*) in the Brick-earth of Crayford," noted by MR. A. SMITH WOODWARD,\* I feel little doubt but that some mistake has been made. The specimen is so much like weathered teeth of Eocene *Lamna*, and we know that derived Eocene fossils are sometimes plentiful in the River Drift of that neighbourhood, so that I should not hesitate to class it as such, in which my colleagues MESSRS. E. T. NEWTON, J. G. GOODCHILD, and C. REID agree with me.

MR. H. N. RIDLEY has found charcoal of the wood of *Castanea sativa*, Mill. (Chestnut) in a bed with palæolithic implements between Crayford and Erith, the only record of the occurrence of the species fossil in this country.†

#### *Alluvium.*

MR. C. REID has noted the following species as occurring in the peat of the Thames, from "specimens from Mr. Spurrell. All the species are still living in the neighbourhood."‡

*Alnus glutinosa*, Linn. Cones. Albert and Tilbury Docks.  
*Cornus sanguinea*, Linn. Albert Docks.  
*Corylus avellana*, Linn. Nuts. Albert Docks.  
*Eupatorium cannabinum*, Linn. Fruits. Tilbury Docks.  
*Sambucus nigra*, Linn. Seeds. Tilbury Docks.  
*Taxus baccata*, Linn. Wood and seeds. Albert Docks.

#### *Analyses.*

Analysis of the Chalk Rock, Boxmoor, by C. W. MEANWELL, "London Geological Field Class: Excursions . . during . . 1888," p. 19. (1889.)

Silicates of iron and of alumina	-	-	·97
Phosphoric acid	-	-	·61
Oxides of lime, of iron, and of manganese	-	-	1·11
Carbonate of lime	-	-	96·77
Loss on ignition, other than carbonic acid	-	-	·11
Sulphuric acid	-	-	trace
			<hr/> 99·57

\* *Geol. Mag.*, dec. iii., vol. v. p. 528. (1888.)

† *Journ. Bot.*, vol. xxiii. p. 253, quoted by C. Reid, *Ann. Bot.*, vol. ii. p. 198. (1888.)

‡ *Ann. Bot.* vol. ii. pp. 180, 188, 189, 193, 194. (1888.)

Another analysis, by P. G. SANFORD, from the same work.  
Specimen dried at 100° C.

Insoluble residue, sand, silica, etc.	-	1.003
Soluble silica	-	.128
Lime	-	54.9
Magnesia	-	.374
Iron and alumina ( $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ )	-	.347
Sulphuric acid	-	.465
Phosphoric acid	-	.713
Carbonic acid	-	42.101
		<hr/>
		100.031

Total calcium carbonate 97.001.  
,, magnesium ,, .785.



# INDEX.

Names of Persons, etc., (authors, observers, and informants) are in small capitals.

Names of Places are in italics, with an asterisk to those outside the district described.

The rest are in Roman type.

The names of the counties in the district are not entered, nor is the name of London, the reader being referred to the various divisions, and to the places in the city, using that word in a broad sense.

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LONDON: Printed by EYRE and SPOTTISWOODS  
 Printers to the Queen's most Excellent Majesty.

For Her Majesty's Stationery Office.

[4758.—750.—5/89.]



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